DCT 209

Development and Evaluation of a Residential Allocation Model Using Time Series Tax Parcel Data in GIS

By

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January 2011

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Executive Summary

Population projections are made available by State and County in Delaware thru the Delaware Population Consortium (DPC) based on a wide range of employment, trend, and demographic data as well as from the input from representatives of many agencies. To support land use and infrastructure planning, county population and housing projections are allocated to areas within the counties to examine where growth is expected in smaller areas within the counties' land use.

Allocations of housing and population projections are currently estimated at traffic zone level (approximately 300 zones in New Castle County) based on first allocating to Census Planning Districts (10 districts), then apportioning to smaller areas based on the fraction of buildable lots of various kinds in each Planning District while considering other factors such as environmental restrictions, current land use, zoning, and historic building trends.

Common scenarios examined by planners include the consideration of community level developments, and the question is how the implementation of various scenarios may affect other communities. For instance, how will a larger or higher density development in one community affect neighboring communities? The ability to examine policy "what-ifs" at the more detailed level of tax parcels is increasingly needed for sub-area or community transportation plans. Travel demand forecasting is moving more toward tax parcel based detail and a great deal of information is available at the property level, and much of it now in geographical information system format.

This project developed a tax parcel based allocation model (binary logistic regression) where factors (independent variables) could be compiled as attributes in a master property table that includes records representing each current, past, and expected future tax parcel. This model estimates the probabilities for available land to be built to meet the demand for housing units as projected by DPC. Factors were explored and a model developed from a 10 year time series from year 1999 to 2009 of tax assessment data and digital property maps linked to master tables for display and reference of the historical data. Where and what residential lots were built for each year can be mapped. A categorization of all tax parcels in New Castle County for all years was developed. The subdivision and creation of new properties was examined.

The model estimating relative probabilities for lot construction was created after an extensive data preparation and examination of many potential factors. Projections were produced and compared to current methods. The result appears to have significant advantages over current methods. The property tables and related GIS maps provide an excellent framework to manage detailed information about properties and allow for easier examination, defense and adjustment of probabilities. The organizational structure could handle other types of land use such as commercial property just as easily. It is much less of a "black box". It is possible with the property data and maps to look at specific current and pending developments. Factors can be adjusted based on new knowledge or scenarios, and new probabilities and allocations can be regenerated relatively easy. The tight correspondence with GIS representations allows for the use of spatial analysis tools to update factors and select areas for study and adjustment. Working at the property level also allows for the incorporation of address based data which opens up a large resource. In contrast to previous methods the step of first allocating housing and population projections to Planning Districts is not necessary.

Factors include ones for capturing current spatial trends in building and presence of supporting infrastructure. Where construction occurs can be considered a competition between available residential lots, controlled by countywide estimates. Development in one area will necessarily affect development patterns in other areas. The modeled relative probabilities capture this competition.

Comparison of a 10 year projection of the previous methods of allocations with the new projections produced in this project showed a very close correspondence. Interestingly for areas of the county where the current projections were much higher than these modeled projections it was shown that there was specific knowledge of development projects that were omitted from the model. Where the model predicted much more construction than the current projection it was shown that current projection omitted development projects taken into account by the model. Adjusting for this new information in the current projection and the model is expected to result in a close correspondence. A difference though is that with the model, master tables can be updated to incorporate changes. Also, detailed parcel maps can display the update, and allocations can be regenerated easily. Adjusting the current aggregate base allocations is a more involved task.

Other factors such as housing value that are not included in the model could be investigated and the model further developed and calibrated. Application of the model to Kent and Sussex counties would be instructive. As data is tracked in the future, the predictive power of the model could be better judged. While model databases include categories for multi unit housing, future development of new multi unit housing is not addressed. The reconstruction or demolition of structures is not included in the model.

Project results indicate that the allocation method developed in this project is very promising as a replacement or augmentation to current methods, and takes full advantage of the more detailed tabular and geographic information now available.

Introduction

Residential projection allocation models assign probabilities to aggregate geographies, such as traffic zones that are derived from and based on historical data such as one, five, and ten-year trends. The historical data often include the number of newly recorded residential lots and number of new constructed residential units. The probabilities are then applied to countywide or regional control totals to estimate the share of total projected growth that may occur in any given traffic analysis zone or census tract. Such methods using spreadsheets and databases are able to efficiently produce aggregate forecasts, however they do not work well for policy or scenario analysis at the tax parcel level. The ability to examine policy "what-ifs" at the more detailed level of tax parcels is increasingly needed for sub-area or community transportation plans.

Common scenarios examined by planners include the consideration of community level developments, and the question is how the implementation of various scenarios may affect other communities. For instance, how will a larger or higher density development in one community affect neighboring communities? Projected development in one area that is different from initial assumptions based on historical considerations, will necessarily affect pre-established expected development patterns in other areas. If the analyst wishes to change the expected growth in one traffic zone, it will alter probabilities and allocations in other traffic zones. Analysts do not have simple procedures to go from an alteration of property level assumptions in one traffic zone to the effects on all others. Also, there has not been considerable research in how property level developments in one area would affect development in other small areas, or in how the effects could cascade in future years. Only a certain amount of growth is seen and possible from year to year. Small areas compete for that growth which is captured by an estimation of the relative probabilities for lots to be built and larger properties to be subdivided.

Since the desire is to work at the tax parcel and community level in scenarios, the larger focus of the research is to examine, at the tax parcel layer, the various factors that contribute to where growth occurs. From this growth modeling the relative probabilities for development at the property level can be estimated and readjusted with various new assumptions and suggested land use configurations. If every lot is equally likely to be developed, or every large undeveloped land track (referred to as a Plot here) were equally likely to be subdivided, then the problem becomes much simpler. Many approaches where data is lacking assume uniform probabilities across developable land categories. But, some factors we would feel comfortable in expecting to make a difference, for instance lots in flood plains are less likely to be built than those not in floodplains. Lots with sewer service are expected to be built at a higher rate. Lots of very small size may have a smaller probability of being built as set backs may be an issue. A long and very narrow tract of land may be less likely to be subdivided. There are also year to year factors related to activity, for instance lots that are within a higher concentration of lots built in the previous year might have a higher probability of being developed. Recent history in this case would indicate this is a "hot spot" for activity. Whether a particular property will be developed in 10 years is a probability, but the probabilities as a whole can lead to a suggested distribution that may be nearer to what is actually observed at larger levels of geography such as a traffic zone.

Working at this very detailed property level required a large data collection and processing effort. Ten years of assessment data were compiled and analyzed extensively. The first step was to categorize land use, whether residential, commercial, open space, protected from further development, or other category. Residential land was categorized as Built, a Lot, or a Plot, where

a Lot is property with little or no structure value less than five acres, and Plots were land tracts with little or no structure value five acres or greater. The categorization led to a specification of "developable land". From year to year (1999 to 2009) the database was developed to track changes in land use, in particular when a lot was built, or a plot was subdivided in any given year. Factors that might affect development potential such as whether a property was in a floodplain, zoning, presence of sewer service, proximity to development activity, land and housing value, and other factors were developed and associated with lots and plots This accounted for perhaps 90% of the effort in the project but yielded a valuable land use product for New Castle County to support modeling and additional studies.

For any given year there is an inventory of between 13,000 and 15,000 available lots for building, but only in the neighborhood of 15 percent of these lots are built, and less in recent years of economic downturn. When a large property is subdivided, a number of "potential" units can be created. How many housing units that can be created with the subdivision of a property is largely dependent on size, zoning, sewer service, and existence of restrictions such as floodplains or wetlands.

Population and housing projections at the Planning District level are available through the Delaware Population Consortium, and this served as the control total for new units needed each year. A model for building of lots and creation of lots from the subdivision of larger properties was developed. Taking each five year population projection by Planning District, units were "developed" to meet the demand based on the relative estimated probabilities, and the result is captured in GIS maps and tables.

Study of travel demand often involves considerations of the effects of specific new development scenarios and therefore a methodology to regenerate and visualize expected effects of various development assumptions is needed. This project demonstrates a procedure to alter land use assumptions and examine expected land use distributions that result. The number of housing units needed at any future time, and the pace of development is constrained to the DPC projections. Predicting the spatial allocation/distribution of development at the tax parcel level within the Planning District is the focus of this research. Rather than having a static projection of where development will occur, a methodology was developed to predict new distributions based on suggested growth scenarios.

PART One, Data Collection and Preparation

Assessment Data 1999 thru 2009

New Castle County Tax Assessment data was available for years 1999 thru 2009. Information of most interest was:

* Land values
* Building values
* Property classifications (Residential, Commercial, Industrial, Exempt, etc)
* Owner (particularly useful for public lands)
* multi-unit dwellings

At the basis of this research is the focus on developing probabilities for development and various factors could be attached to property records such as:

* presence of flood plains
* exempt properties
* agricultural preservation lands
* zoning
* growth areas as defined by the New Castle County Development Code
* proposed development plan activity

The historical information in these files is useful to categorize land use and can be studied to identify development patterns. By examining year to year changes it was possible to determine for each year:

* where built properties are
* which large properties were subdivided
* what lots were created
* what lots were built

Processing and error checking 10 years of assessment data proved to take over a month and a half of processing and compilation time. For the purpose of this study, properties were categorized as in Figure 1 on the next page. Smaller properties, less than five acres were designated as “Lots” or “Built” properties based on the tabulated building values. Properties that were five acres and above were considered large enough to be subdivided and these were termed “Plots”. Through each year there were about 15,000 to 16,000 lots available. Yearly comparisons are shown in Figures 2 and 3.

Figure 1
Yearly Property Categories

Agricultural Preservation
Exempt – (Public and preserved lands)
Commercial
Industrial
Utility
Open Space
Multi Unit
Not Exist – (In a given year a property may not exist)
Removed – based on specific knowledge, removed from consideration for development,

Built Properties
- Very small – 0 to 0.2 acres
- Small - 0.2 to 1 acres
- Medium – 1 to 2 acres
- Large – 2 to 5 acres
- L – 5 to 10 acre property below the canal with SR Zoning and Property value > $60,000 and/or some restrictions

Lots
- Very small – 0 to 0.2 acres
- Small - 0.2 to 1 acres
- Medium – 1 to 2 acres
- Large – 2 to 5 acres

Plots
- Very small – 5 to 10 acres
- Small - 10 to 20 acres
- Medium – 20 to 100 acres
- Large – greater than 100 acres

Farmet
- 10 to 20 acre property in SR zoning below the canal with building value greater or equal to $50,000 (1983 dollars)
- In many cases these were also singled out because of the shape of property or limited access to adjoining roads.

Figure 2, Comparison of Land Use Categories by Year

Frequency of Categories By Year

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Ag Preservation	135	135	130	136	136	136	138	138	138	138	139	137
BLT	214	214	202	204	216	214	204	204	204	206	205	209
BLT large	2483	2516	2553	2597	2619	2651	2676	2707	2714	2725	2729	2727
BLT med	4473	4569	4660	4785	4858	4929	5002	5050	5092	5121	5137	5136
BLT small	54600	55681	56705	58009	58984	59834	60812	62045	62733	63198	63302	63379
BLT very small	76248	77124	77945	78961	79823	80700	81519	82451	83047	83542	83802	83801
BLT-C	684	676	672	670	665	659	644	622	647	639	629	628
COM	7066	7174	7175	7089	7205	7694	7698	7673	7649	7768	7761	7508
EXEMPT	4968	4913	4939	4855	4827	4578	4611	4558	4537	4524	4542	5026
Industrial	432	432	450	449	453	443	443	443	442	441	442	495
LOT	25	1				2					17	235
LOT large	723	710	682	641	617	594	588	565	577	580	574	574
LOT med	1138	1060	986	866	824	779	717	698	682	669	665	665
LOT small	6915	6555	6268	5654	5979	6006	6202	5966	7107	7295	7424	7422
LOT very small	7199	7101	7541	6867	7040	6644	6531	6159	6421	6743	6664	6664
LOT-C	259	242	225	232	227	220	248	202	235	225	226	226
MULTIUNIT	842	843	843	846	846	850	852	857	862	870	876	876
OPENSPACE	1856	1899	1982	2013	2159	2221	2306	2371	2478	2515	2529	2529
PLOT	11	10	6	5	7	6	6	4	4	3	3	7
PLOT large	192	193	187	187	187	186	185	186	185	183	176	176
PLOT medium	540	545	543	545	550	550	549	557	564	554	547	547
PLOT small	788	794	799	811	819	828	838	855	884	894	891	891
PLOT very small	769	777	780	785	786	793	796	804	814	817	822	822
Utility	197	197	198	198	198	197	197	197	197	196	206	192

Figure 3, Comparison of Year 2009 and 2001 Categories

Category Type	% of 2001 properties	% of 2009 properties
Built	80	81.5
Lots	9% (about 15 to 16k)	8 (about 15 to 16k)
Plots	1.3%	1.3
Exempt	2.8%	2.5
Commercial and Industrial	4.5%	4.3

Master Tax Parcel Map

There are general location fields in the New Castle County Tax Assessment files such as what Census County Division, traffic zone, or zipcode the property is located. To determine a better understanding of how properties are distributed and to analyze changes from year to year at the tax parcel level requires tax parcel maps. CADSR had a series of digital tax parcel maps at various times of the year mostly in the fall of each year. These show development through the decade at a very detailed level.

Figure 4, CADSR New Castle County Parcel Map Series

1999 - Dec 3
2000 - Sep 14
2001 – Sep 28
2002 – Sep 30
2003 – Sep 8
2004 - Aug 31
2005 – Dec points, June 5 lines
2006 – Oct 16
2007 – Nov 14
2008 – Sept 22
2009 – Feb 13
2010 - April 13
2010 – Nov 29th

A master digital parcel map was made by combining these years. The master was useful for mapping assessment data at various times, assigning additional factors at a more detailed level of geography, and for error checking. The Master Tax Parcel Map is what is used in parcel maps for this project. Toward the close of the project a November 29th, 2010 New Castle County was added to the data collection to be used for projections, but this was not incorporated into the masters used for modeling.

Development Potential

A larger property could be subdivided, and a number of new lots could be created. A "development potential" could be assigned equal to the estimated number of housing units or lots that could be created. A housing unit or a property categorized as a "Lot" is assigned a development potential of one. A "Plot" which is a category for properties ranging from five acres to over 100 acres has the capacity for further subdivision. The potential units from any plot was determined based on the zoning for that property, and adjustments that could be applied based on the presence of floodplains or other restrictions. The New Castle County Unified Development Code assigns net and gross housing unit densities (units per acre) for each zoning class, and these were used to develop the potential units that could be created in each plot.

Fi**gure 5, Estimation of Potential Units for Plots**

Zoning	Potential units Estimate
S	Acreage / 0.8
SR	Acreage / 5
SE	Acreage / 3
ST	Acreage / 0.35
NC2a	0.75 * Acreage / 2
NC40	0.75 * Acreage / 1
NC21	0.75 * Acreage / 0.5
NC15	0.75 * Acreage / 0.66
NCpud	0.75 * Acreage / 0.33
NC10	0.75 * Acreage / 0.25
NC6.5	0.75 * Acreage / 0.16
NC5	0.75 * Acreage / 0.125
NCmm	0.75 * Acreage / 0.125
Nga	0.75 * Acreage / 0.05
NCap	0.75 * Acreage / 0.025

Figures on the next pages show tabulations of potential units and existing units by Census County Division. From these, it is evident which areas are reaching their maximum growth and which areas are growing. Examining the sum of potential units and existing units provides a complete build out estimate and for New Castle County, total housing unit numbers fluctuate around 260,000 using this method. A good understanding of the potential for development and build-out is useful for the planning process. Due to the scope of the project, there was a limited amount of time to establish categorizations and estimates at the tax parcel level. They represent a best first guess at figures to use in developing a methodology. It is envisioned that if such a parcel based approach was pursued there would be systematic updates and refinements each year.

Figure 6, Estimate of Potential Units by Year by Census County Division

CCD	1999	2000	2001				2002	2003	2004	2005	2006	2007	2008	2009	2010
Brandywine	1428	1338	1295	1288	1277	1363	1314	1264	1296	1267	1307	1299			
Central Pencader	8417	8104	7504	6648	6635	5989	5790	5690	5976	6009	5803	5739			
Greater Newark	2099	2037	1689	1645	1601	1572	1545	1494	1465	1225	1224	1224			
Lower Christiana	455	567	605	616	551	551	513	460	473	467	468	462			
Middletown-Odessa	41172	41304	39640	38880	39438	39236	39339	38971	41072	40942	39737	39731			
New Castle	4815	4901	5083	4945	5698	5439	5200	5067	5207	5161	4662	4646			
Piedmont	4906	4960	4747	4641	4572	4591	4537	4482	4485	4528	4470	4467			
Pike Creek-Central Kirkwood	1089	1053	959	880	868	860	879	970	1105	1090	960	958			
Red Lion	1821	1839	2053	1917	1953	1918	1818	1964	1868	1771	1569	1567			
Upper Christiana	1780	1445	1373	1225	1137	1030	971	1042	984	977	807	806			
Wilmington	1175	1123	1089	1098	1203	1433	1393	1239	1315	1093	1088	949			
Total	69157	68671	66037	63783	64933	63982									

Figure 7, Estimate of Existing Units by Year by Census County Division

CCD	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Brandywine	32508	32571	32626	32651	32690	32707	32760	32899	32931	33059	33109	33109
Central Pencader	11340	11889	12418	12921	13525	13961	14262	14543	14650	14824	14847	14846
Greater Newark	23002	23112	23203	23317	23369	23419	23454	23553	23609	23859	23792	23868
Lower Christiana	13731	13765	13804	13836	13902	13948	13998	14063	14015	14096	14106	14106
Middletown-Odessa	8856	9522	10164	11107	12009	12721	13572	14509	15192	15922	16147	16145
New Castle	30716	30858	31064	31280	31419	31681	31930	32345	32435	32620	32660	32659
Piedmont	10448	10474	10578	10687	10742	10888	10947	11044	11029	11078	11102	11100
Pike Creek-Central Kirkwood	16072	16113	16210	16290	16304	16316	16342	16399	16407	16461	16481	16481
Red Lion	1995	2099	2146	2294	2388	2511	2673	2832	2922	2983	3012	3012
Upper Christiana	9896	10060	10198	10351	10474	10586	10647	10672	10732	10764	10777	10776
Wilmington	25018	25004	25013	25216	25081	25149	25192	25401	25457	25892	25947	25947
	183582	185467	187424	189950	191903	193887	195777	198260	199379	201558	201980	202049

Figure 8, Estimate of Existing Plus Potential Units by Year by Census County Division

CCD	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	
	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Average
Brandywine	33936	33909	33921	33939	33967	34070	34074	34163	34227	34326	34416	34408	34113
Central Pencader	19757	19993	19922	19569	20160	19950	20052	20233	20626	20833	20650	20585	20194
Greater Newark	25101	25149	24892	24962	24970	24991	24999	25047	25074	25084	25016	25092	25031
Lower Christiana	14186	14332	14409	14452	14453	14499	14511	14523	14488	14563	14574	14568	14463
Middletown-Odessa	50028	50826	49804	49987	51447	51957	52911	53480	56264	56864	55884	55876	52944
New Castle	35531	35759	36147	36225	37117	37120	37130	37412	37642	37781	37322	37305	36874
Piedmont	15354	15434	15325	15328	15314	15479	15484	15526	15514	15606	15572	15567	15459
Pike Creek-Central Kirkwood	17161	17166	17169	17170	17172	17176	17221	17369	17512	17551	17441	17439	17296
Red Lion	3816	3938	4199	4211	4341	4429	4491	4796	4790	4754	4581	4579	4410
Upper Christiana	11676	11505	11571	11576	11611	11616	11618	11714	11716	11741	11584	11582	11626
Wilmington	26193	26127	26102	26314	26284	26582	26585	26640	26772	26985	27035	26896	26543
Total	252739	254138	253461	253733	256836	257869	259076	260903	264625	266088	264075	263897	258953

F

Figure 9, Estimate of the Percentage of Total Units That Are Potential Units by Year by CCD

CCD	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Brandywine	4	4	4	4	4	4	4	4	4	4	4	4
Central Pencader	43	41	38	34	33	30	29	28	29	29	28	28
Greater Newark	8	8	7	7	6	6	6	6	6	5	5	5
Lower Christiana	3	4	4	4	4	4	4	3	3	3	3	3
Middletown-Odessa	82	81	80	78	77	76	74	73	73	72	71	71
New Castle	14	14	14	14	15	15	14	14	14	14	12	12
Piedmont	32	32	31	30	30	30	29	29	29	29	29	29
Pike Creek-Central Kirkwood	6	6	6	5	5	5	5	6	6	6	6	5
Red Lion	48	47	49	46	45	43	40	41	39	37	34	34
Upper Christiana	15	13	12	11	10	9	8	9	8	8	7	7
Wilmington	4	4	4	4	5	5	5	5	5	4	4	4
All CCD's - New Castle County	27	27	26	25	25	25	24	24	25	24	24	23

Population Projections and control totals

The Delaware Population Consortium produces population and housing projections for 30 year horizons at the County level. Other agencies take these estimates and allocate them to the Census County Division, also called Planning Districts. This is useful as a starting point to make more detailed allocations. Within each Planning District a certain number of housing units are expected to be "built" on existing lots or lots on newly subdivided properties. The figure below shows one allocation of projections at the Planning District level provided by WILMAPCO in December 2010. These projections go thru continual review and change.

Figure 10, WILMAPCO CCD Housing and Population Projections

New Castle County Households by Planning District- 2011 Series (DRAFT)

Planning District	HH 1970	HH 1980	HH 1990	HH 2000	HH 2010*	HHs to Be built from Development plans	Potential HH Units based on current zoning	HH 2015	HH 2020	HH 2030	HH 2040	HH CHG 10-40	Share of Growth 2010-2040 (2011 Series)	Share of Growth 2010-2040 (2010 Series)
Brandywine	26,379	30,276	31,337	32,292	31,790	1,569	859	32,570	33,030	33,650	33,980	2,190	5.2%	5.1%
Central Pencader	602	2,899	6,140	11,316	13,740	2,704	1,821	14,940	15,800	16,980	17,470	3,730	8.9%	8.7%
Greater Newark	13,105	17,304	20,215	23,151	23,690	701	501	24,090	24,340	24,770	25,090	1,400	3.3%	3.0%
Lower Christina	14,341	14,254	14,304	14,496	13,990	108	357	14,470	14,740	14,960	15,030	1,040	2.5%	1.1%
MOT	2,970	3,816	5,881	9,549	14,380	19,397	6,022	18,710	22,920	31,300	36,990	22,610	53.9%	58.4%
New Castle	14,125	18,799	24,557	30,309	31,840	4,028	1,944	32,950	33,990	35,770	36,860	5,020	12.0%	11.6%
Piedmont	4,200	5,608	8,313	10,654	10,480	1,154	1,099	10,850	11,210	11,940	12,460	1,980	4.7%	4.6%
Pike Creek-Central Kirkwood	8,811	11,255	15,182	17,173	17,510	610	390	17,710	17,880	18,197	18,390	880	2.1%	2.0%
Red Lion	1,003	1,137	1,316	1,906	2,660	471	343	2,840	3,130	3,410	3,620	960	2.3%	1.9%
Upper Christina	2,673	5,274	7,841	9,472	10,210	433	152	10,320	10,440	10,620	10,840	630	1.5%	1.3%
Wilmington	27,565	26,092	28,444	28,617	27,880	561	N/A	28,270	28,470	28,850	29,370	1,490	3.6%	3.4%
New Castle County	**115,774**	**136,714**	**163,530**	**188,935**	**198,170**	**31,686**	**13,488**	**207,720**	**215,950**	**230,447**	**240,100**	**41,930**		
DPC Control Totals					**198,173**			**207,723**	**215,962**	**230,447**	**240,107**	**41,934**		

* Adjusted to reflect new HH control totals from Census

GIS Data Collection

Close to 150 GIS layers and tabular data sets were developed as part of this project and they are made available in a DVD collection. From this, figures and tables in this report can be reproduced and more detailed areas mapped and analyzed. A description of the layers is made available in the appendix.

Main Data Items

The five items below are the projects main data compilations. The master table can be used to form other tabular sets like projections or scenarios. Links to the parcel polygon file (NCPARnov10) allows for visualization and spatial operations on the data.

MastertabFeb11 - Project master table. Contains records for all properties that existed from the year 2000 to November 2010. modeling factors and probabilities are included with a wide range of descriptive data about each historic, present, or future tax parcel. Also includes records for synthetic lots.

Modeltab – a more extensive version of the master table that contains more historical variables, in SPSS format.

NcparNov10 – Most current GIS tax parcel map collected. Matches current properties with records in the master.

Parmaster9910 – A polygon GIS tax parcel map created for all properties from 1999 to 2010 that ever existed. A link to historical parcel data.

SynthptsFeb11 - A GIS point file locating synthetic lots.

GIS Files

Source New Castle County GIS Taxparcel Files (ncYYMMDD)
- Nc101129
- Nc100413
- Nc090213
- Nc080922
- Nc071114
- Nc060816
- Nc050605
- Nc040831
- Nc040831_Project
- Nc030908
- Nc020930
- Nc010928
- Nc000914

NCC_TAZ_2010 – New Castle County Traffic Zones, courtesy of WILMAPCO

Pendingdev2010 – polygon coverage showing properties with Pending status in the New Castle County Subdivision Activity File.
DE_WATERCPCN_070708 – Water Service Providers
PDR – preserved properties
Plotsrestrict – plots that were seen as environmentally restricted, partial
PUB_PRI_OPENSPACE – Public and Private openspace

ZONING10june – New Castle County zoning layer
State_Ag_Districts – State Agricultruarl Preservation District land
Plotdev10 – Plots developed by 2010 in the decade, partial
De-nongrowth – Delaware areas identified as NonGrowth in State land use plan
De-growth-lo – Delaware areas identified as Low Growth in State land use plan
De-growth-hi - Delaware areas identified as High Growth in State land use plan
Lotblt10 – lots that were built in 2010

Lotblt09 – lots built in 2009 and also available for years in the decade
Lots10 – lots in 2010 and also available for years in the decade
Devactivityde10 – New Castle County development activity
Community – community layer for NCC, includes subdivision delineation
Deccd – Delaware Census County Divisions
Sewer_service_areas09 - NCC Sewer Service Areas
Lot09pt – point layer for lots built in 2009, also available for other years in the decade
DE_Floodplains - FloodPlains
Exempt09- Exempt properties in 2009
Indust09 – Industrial properties in 2009
Municipal – municipal boundaries, Fall of 2010
Com09 – Commercial properties in 2009
Vacant_res_lots – Dec 2010 vacant residential lots from NCC Dept of Land Use

A Note on Errors in the Data

Data in this project is at the very detailed property level. Various kinds of errors exist in assessment files and historical tax parcel GIS files. Changes from year to year in how the data was managed sometimes introduces additional errors and anomalies. While a great deal of very time consuming compilation and data checking was done, in this relatively small project it was impossible to go through an exhaustive check of 190,000 + property records. Errors do exist. The data sets created are a good start to an effort to address land use at a more detailed level, and establish a foundation for a powerful information resource for studying development. Working at this detailed level involves considerable ongoing efforts in quality control and update. Examination of development trends could benefit from a continuous update of information as it is made available each year.

Models are based on historic data in most cases without the benefit of detailed information about each property. For instance, a significant probability of subdivision of a property might be assigned where based on other plans of the owner, the probability would actually be near zero. Where there are many properties, each with a relatively small chance of being built or subdivided, accurately predicting action on a particular property from year to year is difficult. It is hoped that the models can show significant and reliable information when predicting patterns for larger areas over longer periods of time.

Master Table Item Descriptions

HANSENKEY – numeric, identifier from NCC Government database
SIGMAKEY - numeric, identifier from NCC Government database
CCDFIPS – string, fips code of Census County Division
CCDNAME – string, name of Census County Division
ZIPCODE – string, zipcode
SHDSTID – numeric, school district id
SCHDIST – string, School District Name
COUNCIL – string,Council District
GRID – string, modified grid
OWNER10 – string, owner in 2010
ACREAGE – number, acreage
LOTNUM – numeric, lot number for synthetic lots
SYNTHLOT – numeric, equals 1 if record is a synthetic lot
PLCLASS – string, Property Class (R, C E, F…)
PROPDESC – string, property description, sometimes for lots
PROP_CLASS – string, property class code
PARCELROOT - string, first 10 characters of PARCELID
PARCELID – string, unique property identify and primary ID of tax parcel
CAT10 – string, Land use categories
CAT10SIMP – string, a simplified version of CAT10
TAZ – string, Traffic zone name
SEWER – numeric, equals 1 if property is in a sewer district
CAT90N – numeric, equals 1 if Lot in 2010 and was lot in 1990
COMLOT – numeric, equals 1 if a commercially zoned lot
INSUBDIV – numeric, equals 1 if a subdivision name is in the assessment database
NOTLOT – numeric, a 1 if record is a synthetic lot
TAZVAR – the total number of built lots in the past 5years in the home traffic Zone divided by the total available lots in the past five years in the home Traffic zone
PROB1115 – calculated probability for lots being built for projection year 2011 to 2015
PROB1115ADJ – PROP1115 adjusted for the number of lots built in 5 year projection period
PROB115pend – probability of lot being built if PENDING development is considered
CAT15 – projected land use categories for 2015
CAT20 – projected land use categories for 2020
Z115 – Z factor in model calculation
Z115PEND – Z factor in model calculation when PENDING development is considered
BLT0610VAR – whether this record is a lot that was built between 2006 and 2010
LOT0610VAR - whether this record was a lot between 2006 and 2010
SUBDIV – subdivision name
PLANSTAT – status in NCC subdivision review process
SIZE – categorization of tax parcel size
POTUNIT10 – potential housing units that could be constructed in this tax parcel

Master Table Item Descriptions (continued)

EXISTUNIT10 – Existing housing units in this tax parcel
PLCLASS – Plan classifier, NCC Subdivision Review
PLANNAME– Plan classifier, NCC Subdivision Review
PLANNAPPNO– Plan application number, NCC Subdivision Review
PLANLOTS– Plan number of lots, NCC Subdivision Review
PLANCMT– Plan comments, NCC Subdivision Review
TOTASS10 – total assessed property value, 2010, in 1970 dollars
TAXASS10 – taxes owed for this property, 2010, in 1970 dollars
LAND10 – land value in 1970 dollars
BLDG10 – land value in 1970 dollars
FARM10 – farm value in 1970 dollars
ESTVALTOT – estimated total value of property in 1970 dollars
VALUEperACRE – estimated value per acre
MAXSALE – maximum previous sale value
MAXSALEDT – maximum sales date
ASS2SALES – Assessed value to sales ratio
ZONING10 – 2010 zoning
BELOWCANAL – is 1 if a property below the C&D Canal
RESTRICTIONS – 1 if presence of environmental restrictions
OPENPUBPRB – 1 if public or private open space
EXEMPT – 1 if exempt
NEARMOT – 1 if parcels around MIDDLETOWN, ODESSA, or TOWNSEND
NEARSMYRNA – 1 if property near Smyrna
SLIVER – generally a property with relatively high perimeter versus area
GROWFACTOR – Growth factor from State land use mapping
AGPDR – preserved agricultural land
AGDIST – Agricultural district flag
MUTYPE, HUTYPE,MUTYPE2 – housing unit types for multifamily housing
MULTYEAR – year became a multiunit
MULTIPOT – housing unit potential for multiunit dwelling
NUMISL – referred to number of distinct polygons making up tax parcel in GIS file
UNIT – unit designator, for multiunit housing
ABEGYEAR, YEARCREATE – when this property came into existence, equals 1998 if before 1999
AENDYEAR – year property went out of existence
BUILTYEAR – year property was built
ORIGINPAR – the parent parcel that was subdivided to form this property
NUMHU – number of housing units on this property
LAND09 – land value in 2009
BLDG09 – building value in 2009
ZONING09A – zoning in 2009
SEWRCONN, SEWRCONS – sewer service district information

PART TWO, Initial examination of the data and candidates for model variables

The Development Process

An area is seen as being made up of "Plots", larger properties that can be subdivided and are available for residential development, and "Lots", properties that can contain housing units, and existing residential and non-residential development. A certain number of plots are subdivided each year to create new lots, and a certain number of lots become built housing units. These are the main processes that are modeled. Factors that may affect where and if development occurs were studied in models to ultimately estimate a set of relative probabilities for development of properties. Two types of development are considered, the subdivision of larger properties into housing unit lots, and building on those lots.

The rate of development is constrained by Delaware Population Consortium Projection estimates. The rate of subdivision and construction is considered independent of the patterns of development over time.

Multi-Unit Housing

Existing condominiums, apartment buildings, and trailer parks are shown in GIS and tabular property files. Most new construction over recent years has been as subdivisions made up of single family detached housing units. It is expected that with the economic downturn there will be an increase in multi-unit housing construction in the future. Examining the market for multi-unit housing was beyond the scope of this project and housing type in general is not addressed, though it is certainly an area of interest when describing the housing market.

Initial View of Lot Data

Lots are identified as properties of less than five acres and no or low (< $2000 in 1976 assessment dollars). Close to 90% of lots are less than one acre, and of these more than half are 0.2 acres or less, as shown in a sample from 2003 below. The category "LOT-C" is for properties that are lots but have a commercial or industrial zoning, although these lots could be used for residential development.

Figure 11, Lots in 2003, New Castle County

	Number	% of lots
LOT large (2 to 5 acres)	682	4.3
LOT med (1 to 2 acres)	986	6.3
LOT small (0.2 to 1 acre)	6,268	39.9
LOT very small (0 to 0.2 acre)	7,541	48.0
LOT-C	225	1.4
Total	15,702	100

The number of lots in New Castle County fluctuates from year to year ranging from 14,000 to 16,000 properties. Between the year 2000 and 2009 there was an average of about 1800 lots built per year, with a maximum of 2365 built in 2002 and a minimum of only 507 in 2009. The effects of the economic downturn could clearly be seen. Figures for total lots and built lots are on the next page. One interesting feature of the this data is that it is clear that at the Planning District Level, the percentage of lots that are built each year varies greatly between the Planning Districts as shown in Figure 14. The City of Wilmington, Brandywine, and Lower Christina Planning Districts show in general a lower percentage of built lots each year than other Districts even though they show several hundred lots in their inventory. Any model created for lot build out would seek to explain this kind of difference.

Where lots were **not** built was studied as much as where lots were built. It can be seen for instance that a newly created subdivision would typically not show building activity until a few years after it was subdivided. For the 10 year period lots which were lots in 1999 and still lots in 2009 were mapped, and reasons why some of these lots weren't developed could be considered. Some were in floodplains, some were of a very small size, and some seemed to be part of urban renewal in the City of Wilmington. This report contains a series of maps showing lots together with lots that were built in the following year. These maps and data are also included in the project data sets.

Figure 12, Example area of lots (red dots) not built since 1990
Northern New Castle County near Naamans Rd.

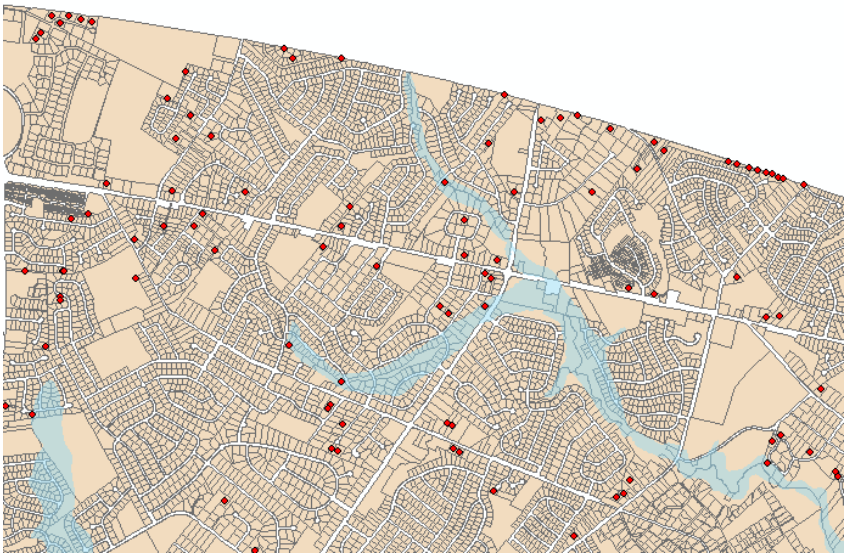


Figure 13, Lots Available by Year by CCD

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Brandywine	762	685	641	634	623	709	664	657	619	588
Central Pencader	3311	2994	2589	2210	1662	1464	1268	1078	1012	1214
Greater Newark	731	622	709	648	593	564	538	486	477	445
Lower Christiana	443	553	593	602	537	537	499	446	453	447
Middletown-Odessa	5890	5870	6097	5714	6069	6049	6843	6482	7854	8184
New Castle	1476	1497	1648	1508	2267	2066	1832	1671	1833	1814
Piedmont	910	809	757	649	625	595	557	519	521	665
Pike Creek-Central Kirkwood	519	437	343	264	252	293	312	413	497	482
Red Lion	391	409	623	481	517	482	382	528	432	391
Upper Christiana	674	693	623	475	347	240	184	256	195	189
Wilmington	1152	1100	1079	1075	1195	1246	1207	1053	1128	1092
Total	16259	15669	15702	14260	14687	14245	14286	13590	15022	15512

Figure 14, Lots Built by Year by CCD

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Brandywine	91	68	38	48	21	57	93	66	40	14
Central Pencader	553	528	507	619	367	300	280	117	56	24
Greater Newark	155	90	89	66	48	41	65	35	29	10
Lower Christiana	1	22	31	80	60	52	71	18	26	17
Middletown-Odessa	631	650	949	966	699	854	839	720	555	232
New Castle	204	205	213	215	272	255	389	158	120	61
Piedmont	105	115	109	60	48	61	49	15	24	13
Pike Creek-Central Kirkwood	87	99	81	45	10	28	47	38	33	22
Red Lion	103	53	147	100	121	170	148	100	57	32
Upper Christiana	175	137	150	127	109	59	29	68	12	16
Wilmington	48	25	51	26	29	67	161	69	75	66
Total	2153	1992	2365	2352	1784	1944	2171	1404	1027	507

Figure 15, Percentage of Lots Built in the Following Year

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Brandywine	12	10	6	8	3	8	14	10	6	2
Central Pencader	17	18	20	28	22	20	22	11	6	2
Greater Newark	21	14	13	10	8	7	12	7	6	2
Lower Christiana	0	4	5	13	11	10	14	4	6	4
Middletown-Odessa	11	11	16	17	12	14	12	11	7	3
New Castle	14	14	13	14	12	12	21	9	7	3
Piedmont	12	14	14	9	8	10	9	3	5	2
Pike Creek-Central Kirkwood	17	23	24	17	4	10	15	9	7	5
Red Lion	26	13	24	21	23	35	39	19	13	8
Upper Christiana	26	20	24	27	31	25	16	27	6	8
Wilmington	4	2	5	2	2	5	13	7	7	6
Total	13	13	15	16	12	14	15	10	7	3

Figure 16, Year 2001 Lot Data In Southern New Castle County

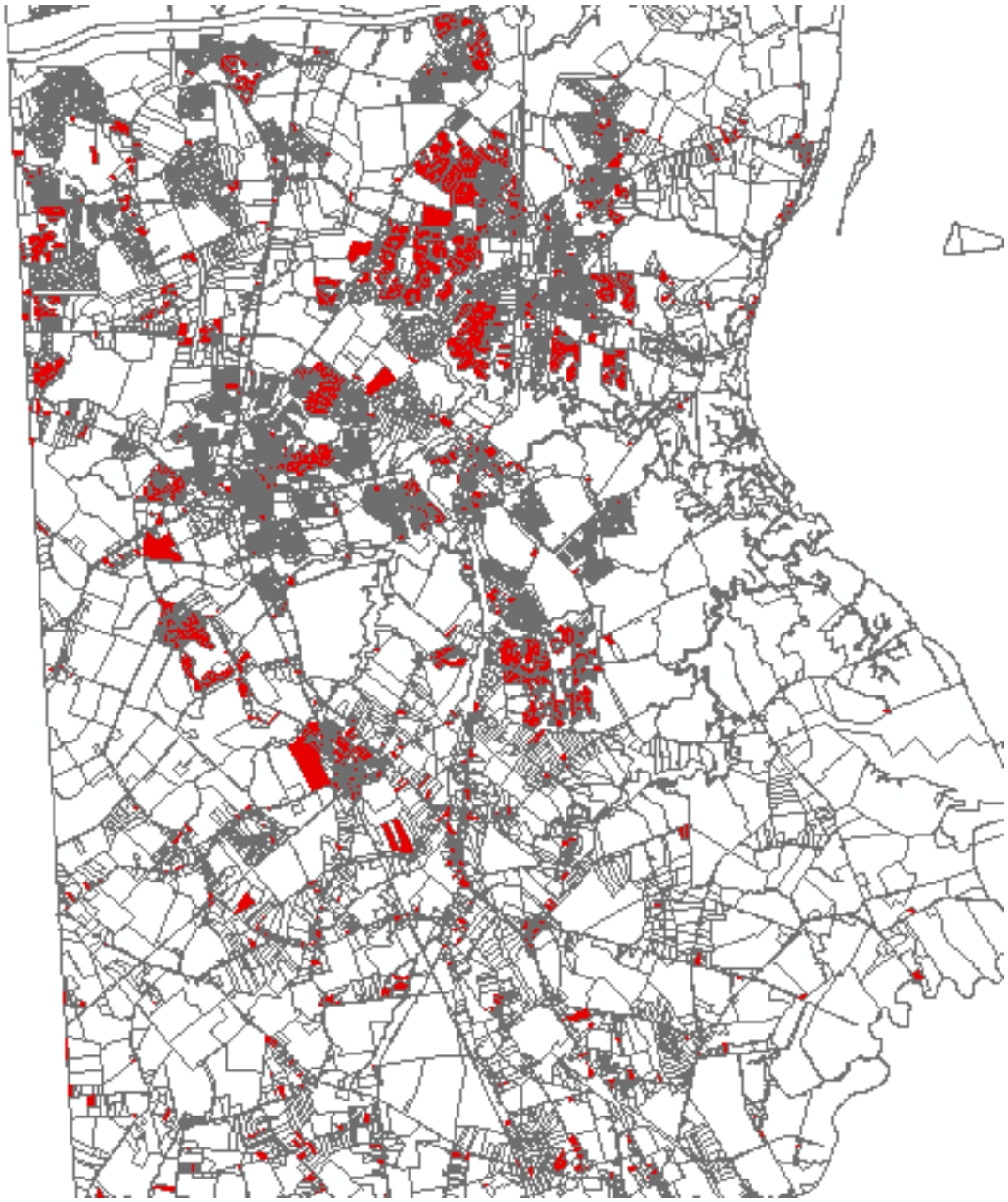


Figure 17, Year 2001 Lot Data In Northern New Castle County

Figure 18, Lots in 2001 with Lots Built in 2000
Green Dots = 2001 Lots Red Dots = Lots Built in 2000
Tax Parcel Base Sept 2001

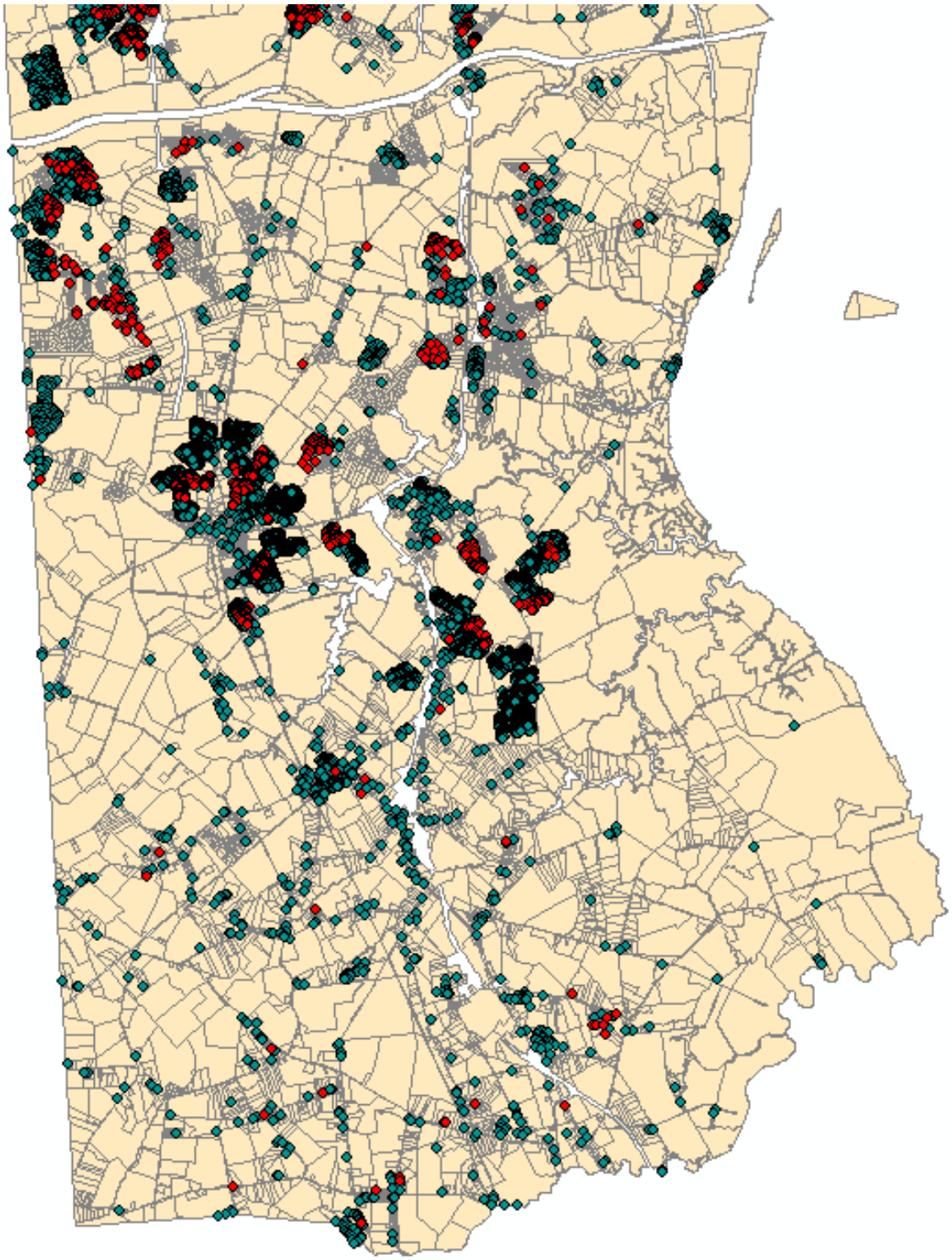
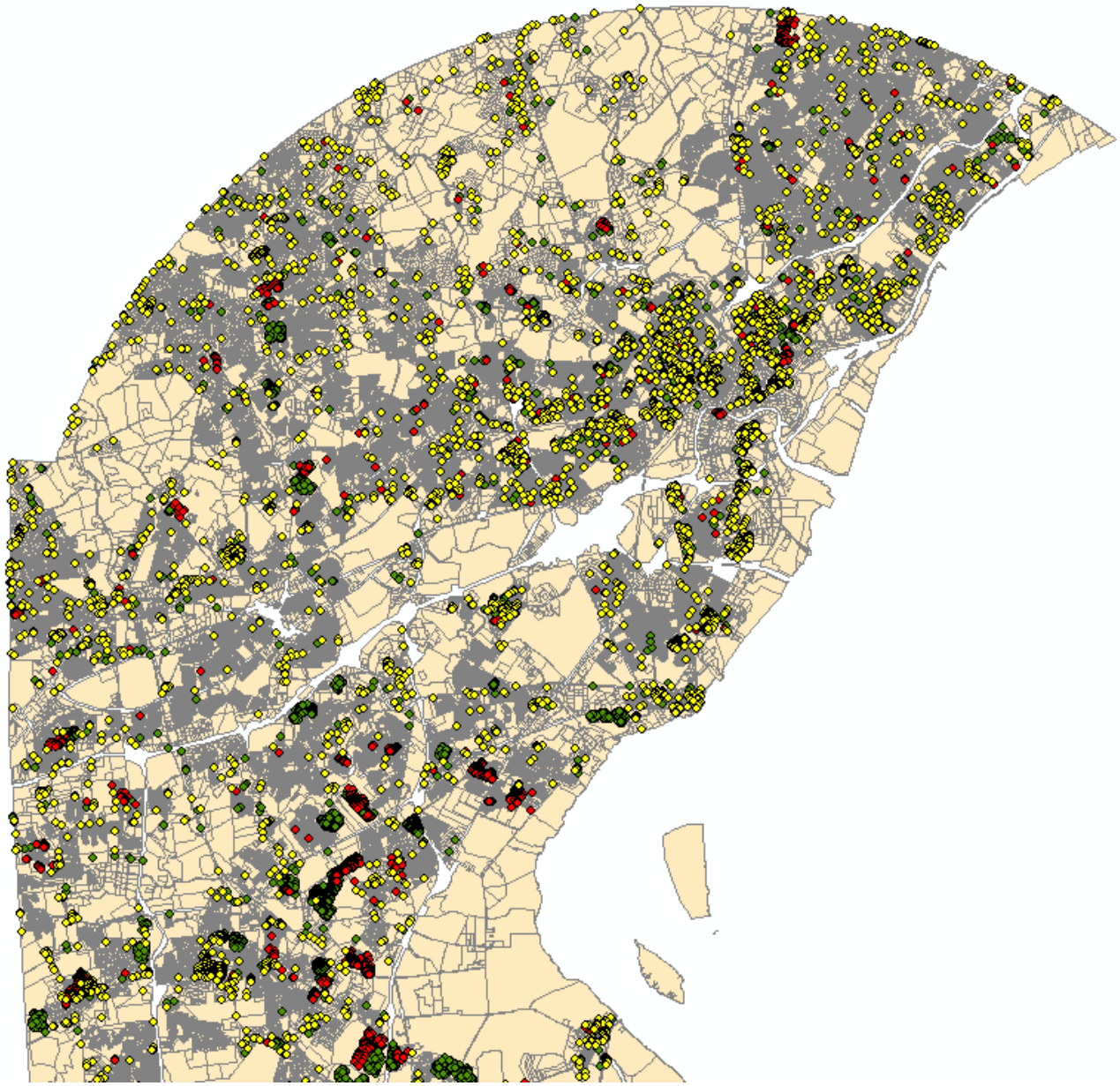


Figure 19, Year 2007 Lot Data In Northern New Castle County
Green Dots = 2007 Lots Red Dots = Lots Built in 2006 Yellow Dots = Lots from 1999 to 2009
Tax Parcel Base November 2007



Factors Considered for Estimating Probability of a Lot Being Built

There are a number of factors that would influence where the development of lots would occur. The list of factors included for study and associated with each property in the master property data for years 1999 thru 2009 include:

Size in Acres – In particular it is expected that lots are of very small size
Sewer District – Lots not in served by a sewer system in particular. Could be a useful factor to view different parts of the county as well.
Flood Plains and Wetlands – Lots in floodplains and other environmentally restricted areas are not expected to be built
Lot Age – If a property was a Lot for the past 20 years, for unknown reasons it is expected that it is less likely to be developed in the future. On the other side of this, Lots just created generally see a lag time (like a few years) before building starts.
Proximity to Building in the Previous Year – If lots are available near a high number of lots that were built in the previous year this could be an indicator of expected activity.
Zoning – Most lots are of a residential zoning category, though some have commercial or industrial zoning. These are eligible for residential building though it is expected that these will have a different development pattern. Most subdivisions are in the Suburban zoning category with few being in Suburban Reserve (SR) or Suburban Estate (SE)
Place Factors – For instance, lots below the C & D Canal may be built at different rates. City of Wilmington lots appear to be different than lots in non-urban areas.
Sewer Service Areas – Plots with access to the county sewer system or within a designated sewer district.
Percentage of Community that Is Built

Development Factors Related to Proximity to Existing Development or Activity

One type of factor was of particular interest. If it is shown that the probability of a plot being subdivided or a lot being built depends on the proximity of existing development or where plots were previously developed or lots built, then the probability of where development occurs needs to be estimated in an interactive process year to year. It is often thought that development activity occurs around other activity. On the other hand if where development takes place does not depend on where it took place before, then development patterns would be expected to be the same through time, and only affects development in other areas to the extent that places would be competing for a limited housing demand. As development is limited by estimated control totals produced by the Population Consortium, the effect of a scenario that postulates that a particular property(s) will be subdivided and built before others will generally be to postpone the expected subdivision of other properties to a later time and probabilities won't have to be adjusted from year to year.

Initial View of Plot Data and Factors for the Development of Plots

Plots are defined here as those non-commercial properties greater than five acres and are what can be considered developable land. Not included in this category are public and other exempt lands including open space set asides, agriculture preservation areas and other preserved or protected lands, and existing multi-unit complexes like condominiums and trailer parks.

Figure 20, Plots in 2009

	Number	Percentage of Plots
Very small – 5 to 10 acres	822	34%
Small - 10 to 20 acres	891	37
Medium – 20 to 100 acres	547	22
Large – greater than 100 acres	176	7

Larger tracts of developable land mostly occur just above the Chesepeake & Delaware Canal. Maps of plots and developed plots are shown on the next pages.

Various factors were developed and examined for plots to use in modeling the probability for a plot to be subdivided/developed.. These factors include:

Zoning = SR = Suburban Reserve
Zoning = SE = Suburban Estate
"Slivers" - Properties where the ratio of perimeter to area was greater than 150, generally longer thinner properties. This type of property often exists in the bottom quarter of the county in the suburban reserve zoning category, and many of these were classified as "farmets" and considered as built properties rather than as developable land.
Size in Acres
Growth Areas – The State Development Strategies mapping categorizes areas as No Growth Areas, Low Growth Areas, and High Growth Areas
Below the Canal – Properties below the C & D Canal
Built Factor / Proximity to Existing Development – The number of existing housing units within a mile from plots was calculated. The average number of housing units for all plots was roughly 1000 where the average for plots that were developed was a little over 2000. A factor was built where a "1" corresponded to plots having over 1500 existing housing units within a mile.
Environmentally restricted properties - 5% of properties that were partly within floodplains were subdivided.
Exempt, Open Space,Public Lands, Ag Preservation – No properties of this type were subdivided. They are placed in their own categories and not listed as Plots.
Sewer Service Areas – Plots with access to the county sewer system or within a designated sewer district.

Present in New Castle Counties Subdivision Review Process Database– Probably the most reliable factor that would indicate development in the near term. All subdivided plots go through this process.

Land Value – in 1974 dollars the average value in dollars per acre is about $5000 for all plots, and about $6700 for developed plots. Processing of property values from assessment files (assessed values) was difficult and perhaps left to further research and processing.

Zoning of course has a major effect on the probability of development. Suburban Reserve and Suburban Estate zoning classes were only developed at 2% rate in the study period. Related to this are the State Growth Areas where No Growth Areas includes SR and SE zoning. Also related to the zoning factors and growth area factors is where no sewer service is available. Only 3% of plots that were developed were in areas outside of county sewer districts. Larger plots, those greater than 20 acres, tend to be developed at a higher rate than smaller plots. Plots nearer the towns of Middletown, Odessa, and Townsend were developed at a slightly higher rate than other plots. About half the developed plots were above the C&D Canal, and about half were below. Where about 67% of plots are below the canal, the development of plots above the canal was slightly higher though plots above the canal are often smaller. When mapping plots, it seems visually that subdivided plots tend to cluster, and this is shown by a higher value for proximity to existing development. The percentage breakdown for developed plots and all plots is shown in the figure below. Figures mapping land use in plots, sewer service, and growth areas are shown on the next pages.

Figure 21, Plots by Zoning

	% Developed Plots	% All Plots	Number of Plots
Zoning SR	2	40	1034
Zoning SE	2	9	225
Not a "sliver"	79	52	1356
Size 5 to 20 acres	38	68	1779
Size 20 to 100	62	32	823
Near MOT	22	10	254
> 2000 blt factor	36	17	449
> 1500 blt factor	43	22	2024
No Growth Area	4	53	1375
Low Growth Area	73	42	1092
High Growth Area	23	5	136
Below C&D Canal	55	67	849
Size 5 to 10	17	33	854
Size 10 to 20	21	35	921
Size 20 to 100	39	24	616
Size > 100	23	8	207
Restricted (Floodplains)	7	17	459
No Sewer Service	3	54	1404

Figure 22, Land Use Below the Canal, Plots in Blue

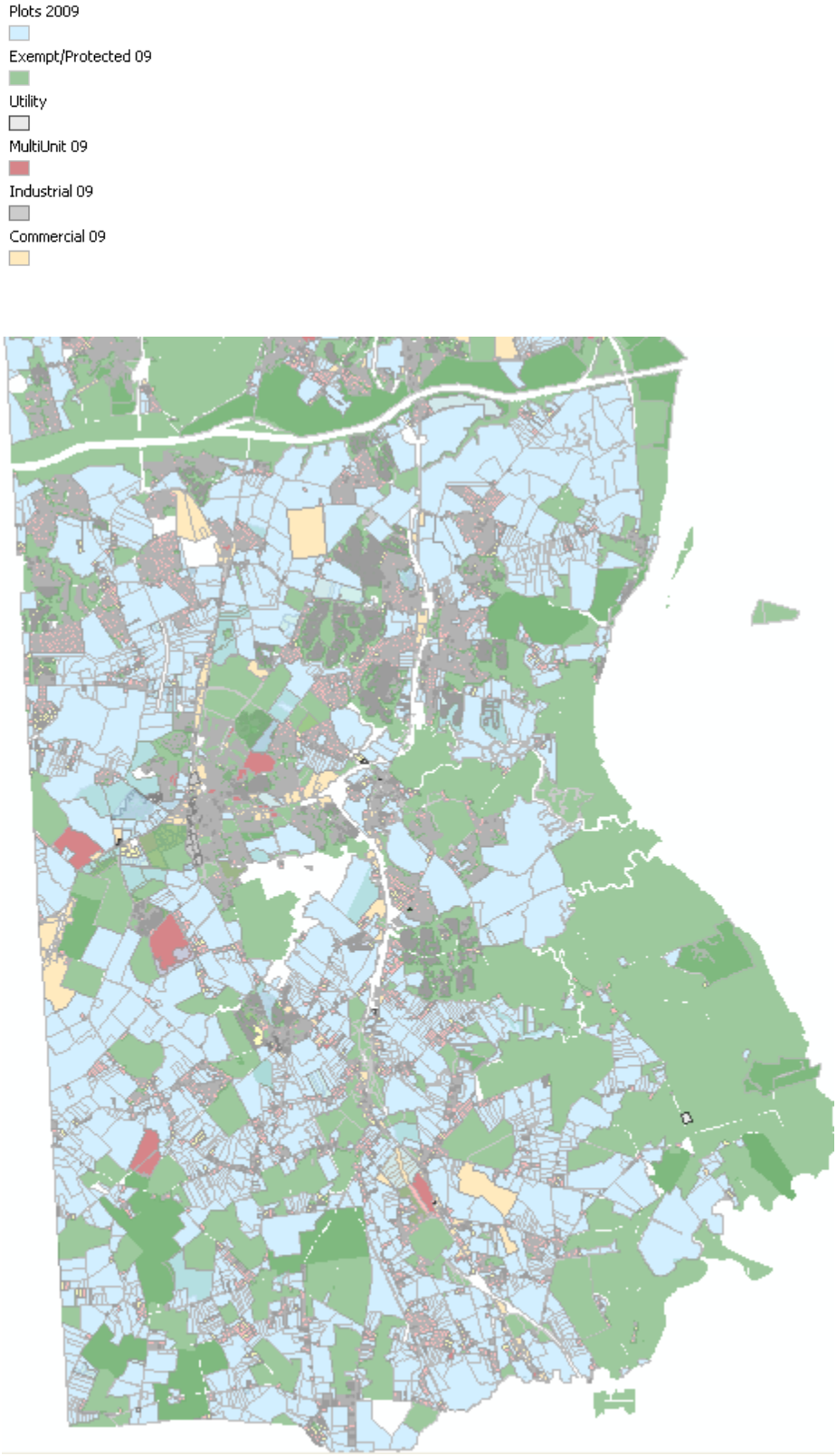


Figure 23, Land Use Above the Canal, (Plots in Blue)

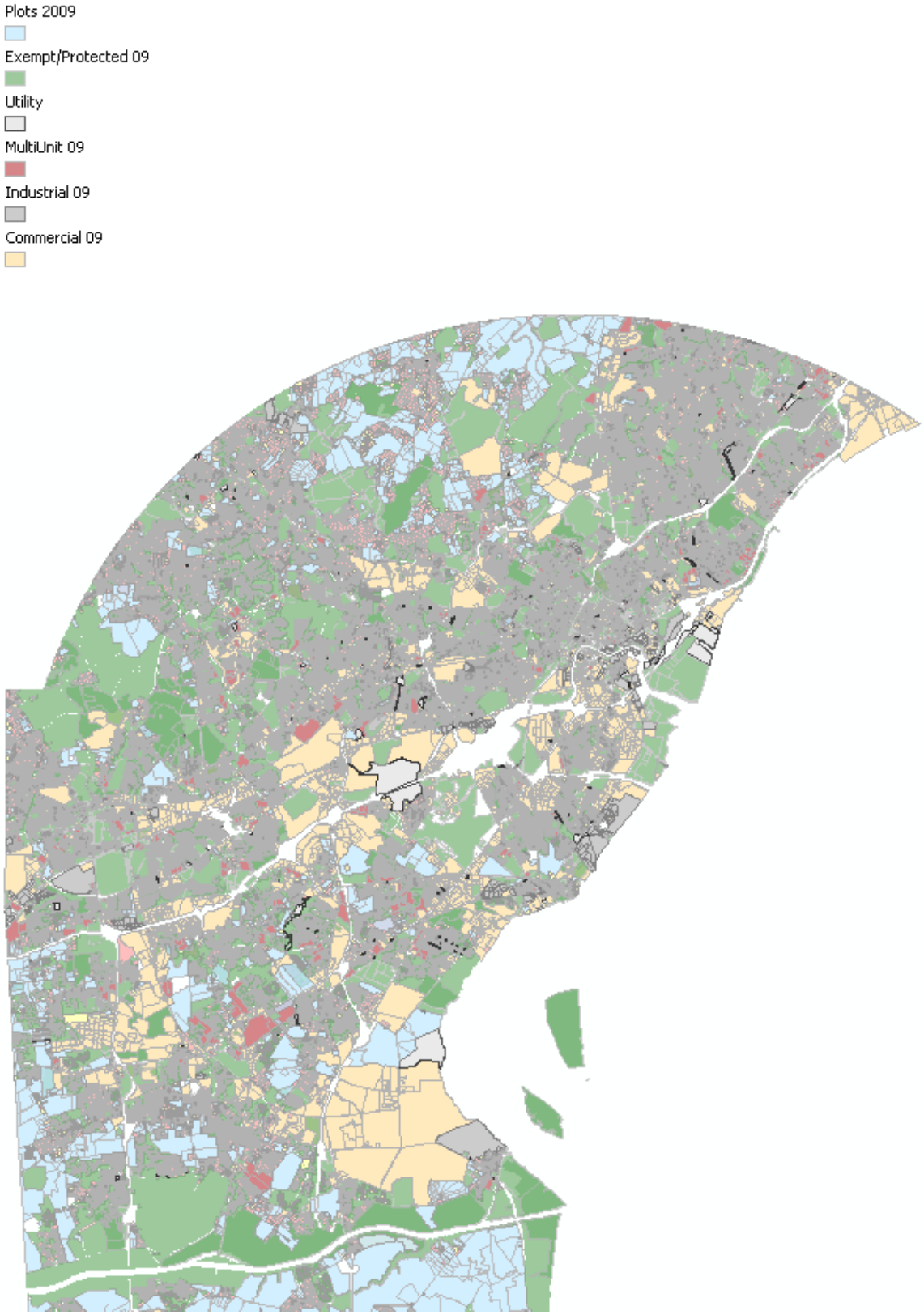


Figure 24, Plots That Were Developed in Northern New Castle County between 1999 and 2009 (Shown with purple shading)

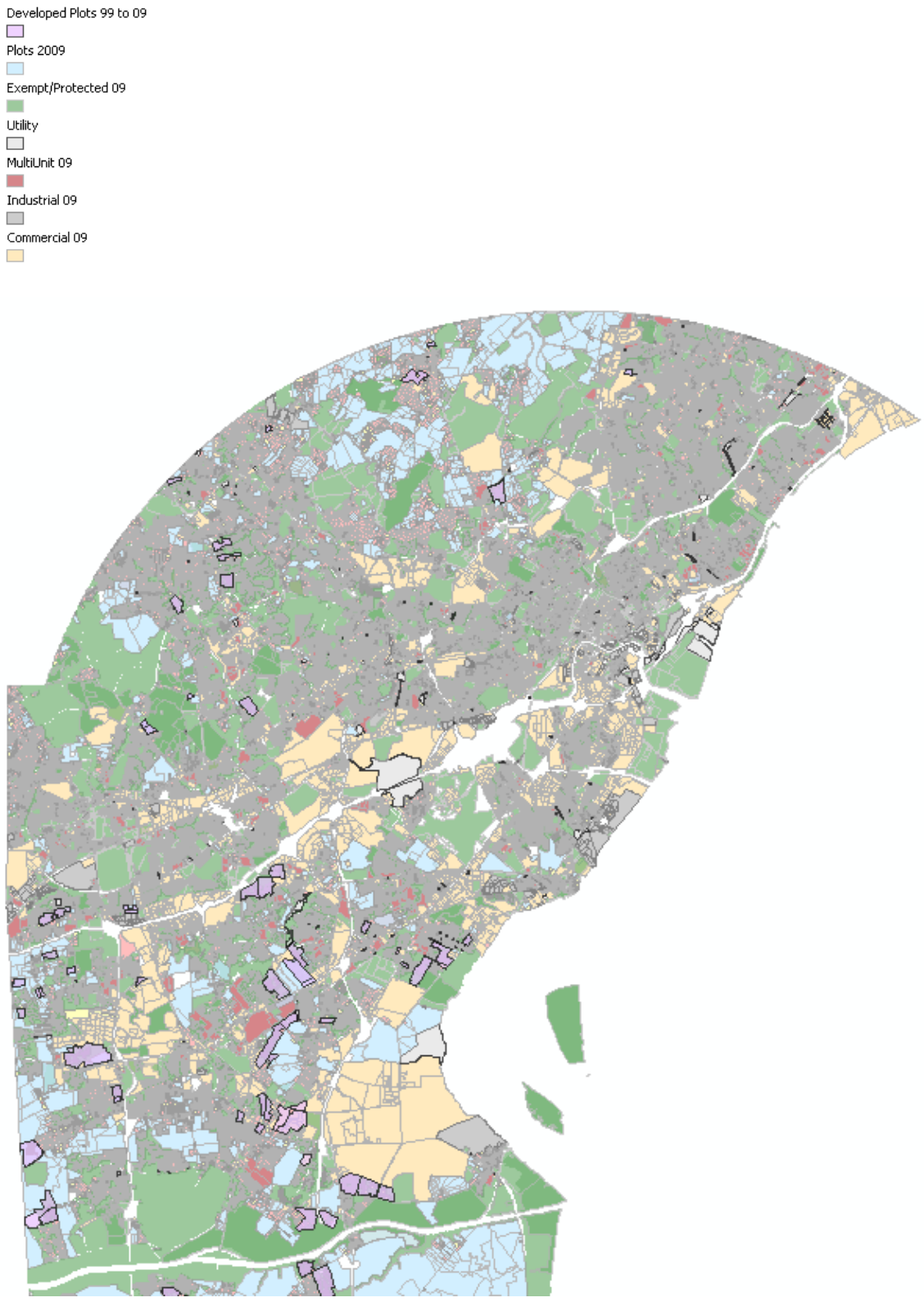


Figure 25, Plots That Were Developed in Southern New Castle County between 1999 and 2009, (Shown with purple shading)

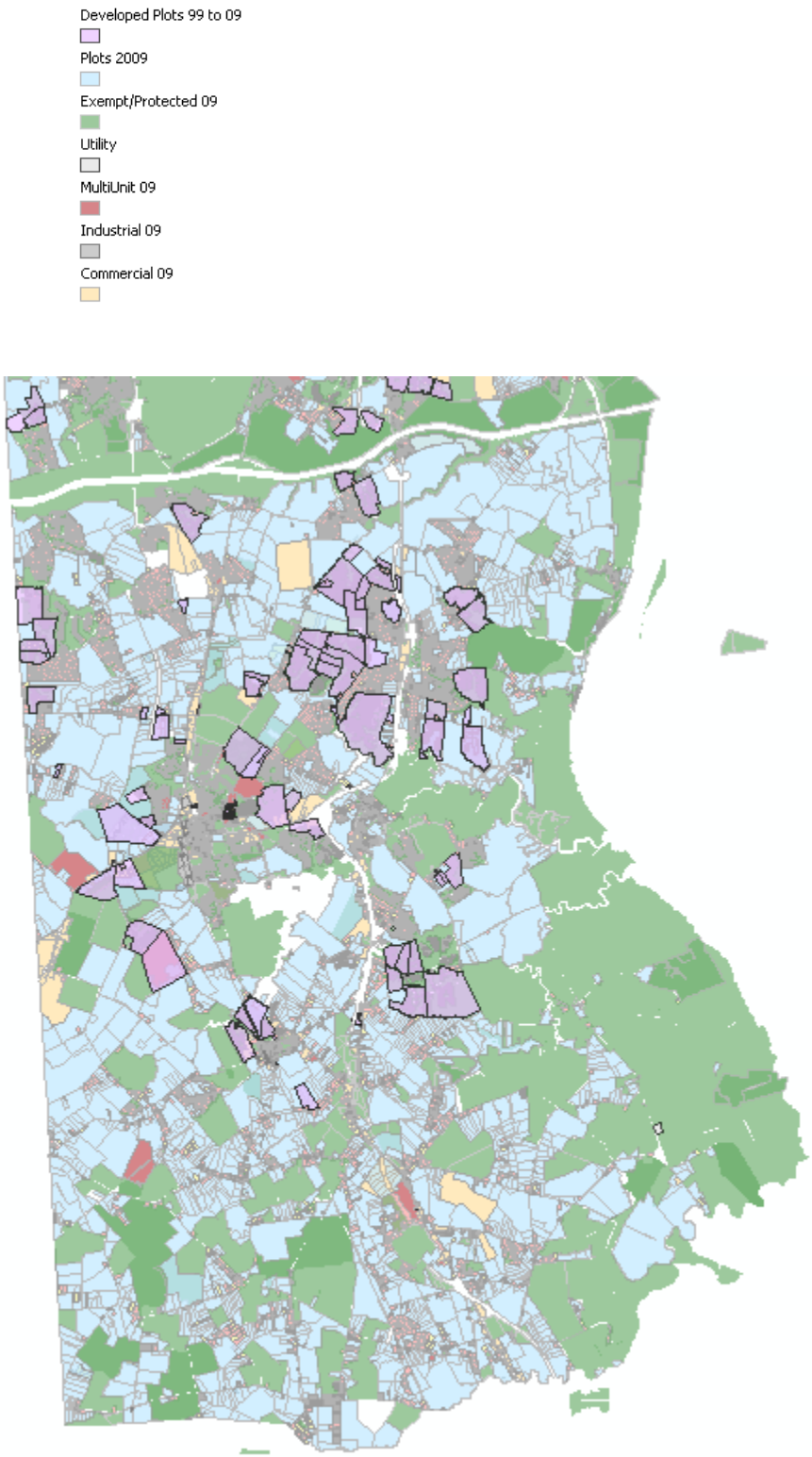


Figure 26, Sewer Service Areas in New Castle County (shown in blue)

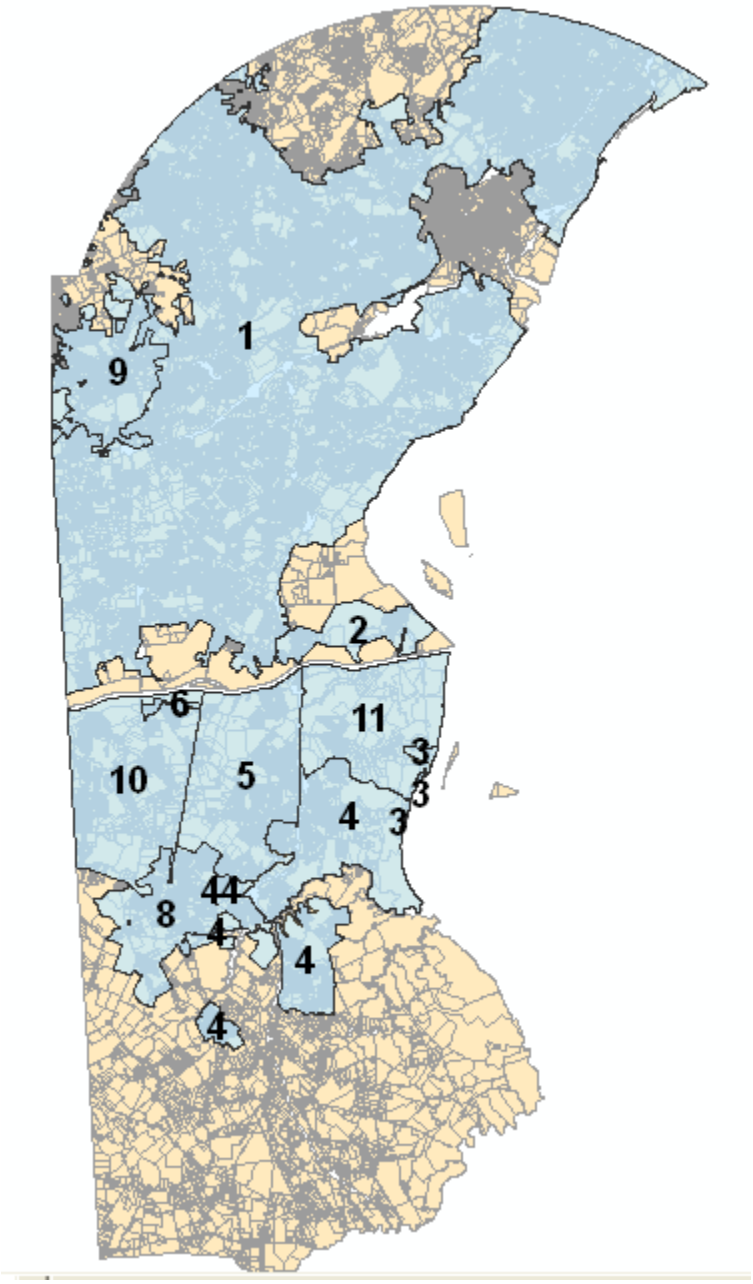
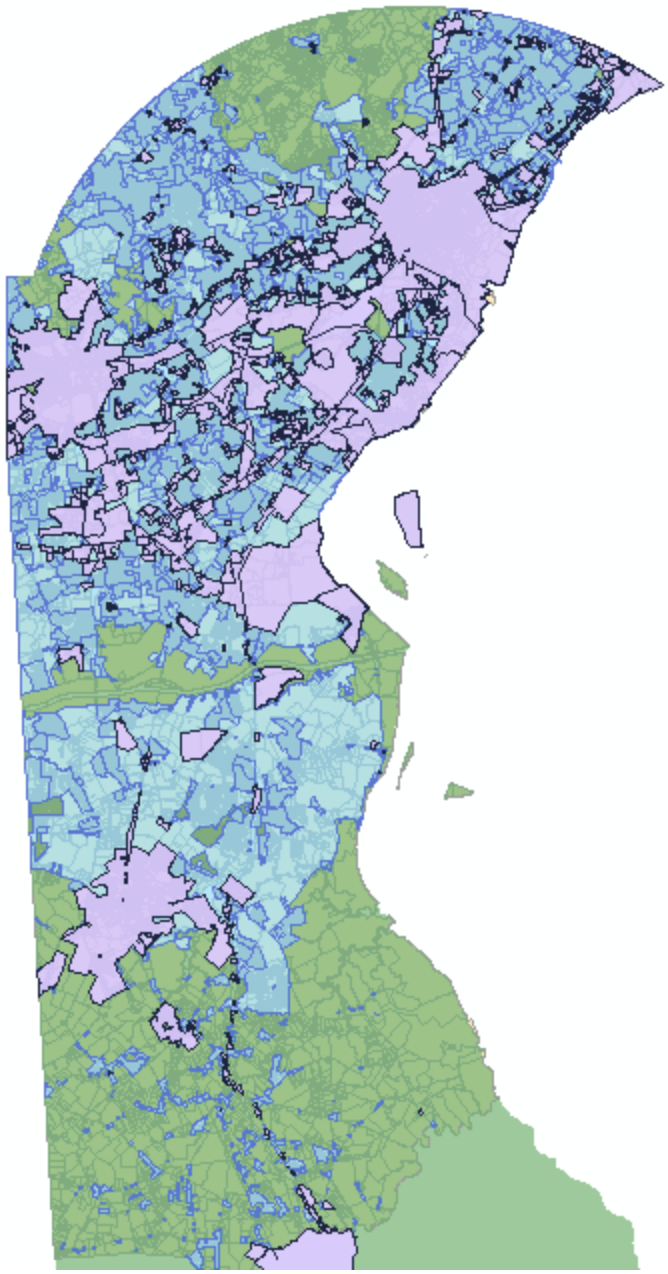


Figure 27, State Land Use Strategies in New Castle County (Areas of High Growth in purple, Medium Growth in blue, and Lo Growth in green)



PART Three, Development of the Model

The allocation of population and households to traffic analysis zones (TAZ) in Delaware has been done annually in New Castle County and infrequently in the Kent and Sussex counties. The allocation process follows a fairly straightforward method from the top down. First, the expected households were taken as a given by the most recent projection of the Delaware Population Consortium (DPC) for the three counties. In a second stage, the projected increase in households was allocated to the 27 census county divisions (CCD) in the state by county. This is done largely by trend and/or shift/share with input from local planners.

In the second stage of the allocation process, all available land that was deemed buildable was summarized by modified grid (a commonly used small demographic unit used in Delaware) . Land that was dedicated open space, in flood plains, in agricultural reserves, in recognized wildlife habitats, or was zoned inappropriately for further subdivision was excluded. This buildable land was categorized into groups (existing lots, lots in new sub-divisions, un-subdivided residential land, and farm land) within a given modified grid. Un-subdivided land was split into synthetic lots of a size consistent with recent activity in the CCD.

In the third stage, the estimated lots in the modified grid are accumulated with varying arbitrary weights. Existing lots and lots in new subdivisions have a weight of 1, un-subdivided residential land a weight of 25, and farm land was weighted by .10. With the weighted lots available for each modified grid, each modified grid received the proper proportion of the projected units allocated to the CCD as determined by their share of weighted lots. Experience has shown that this process does not truly reflect the concentrated nature of most development. It also does not utilize much of the attributes readily available about each lot. At the end of the process there was a necessary adjustment process driven by experienced planners conducted at the grid level before aggregating the grids into the TAZ's.

This research is meant to improve on this process by developing a model that operates at the parcel/lot level rather than the more aggregate modified grid level. The model will estimate the probability that each available parcel will be built over a five year period. A model based on this period is justified by the DPC projection process and the inherent volatility associated with shorter periods of time.

In order to build this model, each available parcel in the year 2000 assessment database provided by New Castle County was followed annually from the base year through 2005. At the end of the period, the dependent variable took on a value of 1 if it had been built and zero otherwise. In actuality this process was done backwards from 2010 in order to account for the fact that many parcels in 2000 were subdivided in the intervening years. Thus, a parcel that was built by 2005 may not have existed in 2000. Finally, a binary logistic regression model was selected as the most appropriate one to estimate for this situation.

The independent variables were selected from a large set of candidate variables computed from the 10-year time series of factors developed from the assessment files and GIS mapping overlays. The final set included variables which had both positive and negative expected relationships to the probability that the particular lot would be built. For example, if a lot is in an existing sewer district, then it should have a higher probability of being built compared to those that are not. On the other hand, if a lot has been in existence for the last 20 years and yet hasn't been built, it should have a lower probability than newer lots. This was an indication that the lot may be irregular or otherwise impaired. Two other variables in the model, both dummy variables, indicated whether the lot was in a subdivision and whether the lot was classified as commercial. The first was anticipated to have a positive sign and the second was expected to have a negative sign.

The more interesting question involved how best to incorporate the spatial distribution of growth. In a sense, this was done previously by allocating households first to the Census County Division (CCD) level. In this model, that could be accomplished by introducing dummy variables, one for each CCD less one that would be contained in the constant term. Essentially each CCD variable measures the difference in the probability that a parcel will be built given its current location relative to the omitted CCD. When the forecasted probabilities are summed across all parcels in a given CCD, a forecast of the new units in each CCD is obtained independent of the allocation procedure described above.

While the CCD approach is useful, a close examination of the development process over the past decade suggests a more disaggregated approach would come closer to predicting actual development. Most development has come in small clusters dictated by the subdivision planning process. While subdivisions are not fully developed over night, they tend to be completed within a 15 year time frame other things equal. This clustering suggested the need for a smaller spatial area than that represented by the CCD. The most obvious choice was the Traffic Analysis Zone (TAZ). The metric was defined as the percentage of available lots at the beginning of the period that was built during the time period. Said another way, for the preceding five year period, the number of lots that were built divided by the number of lots available in each traffic zone during the previous five year period, forms a ratio for each traffic zone which was a TAZ based factor associated with each lot. For the first five year period, the measure is highly correlated with the probability that a given property will be built. Since the objective is to project the future probability of construction, the model utilizes the measure lagged one period, i.e. the variable in 2006-2010 reflects the patterns in construction in 2001-2005. To fully implement this variable, a measure for TAZ activity was developed for the 1996-2000 period. This variable was included in the 2001-2005 equation.

Residential housing construction has been anything but stable in this decade. For the first 6 years 2001-2006, more than 2000 units (excluding multi-family) were constructed annually. Then in the year following the financial crisis, this number was halved to 1000 then again to 500. There has been a modest rebound to 1000 in 2010. This raises the question as to whether a model built on 2001-2005 is at all similar to that for 2006-2010. If they were substantively different, then it might raise questions about the accuracy of

forecasts in subsequent five year periods e.g. 2011-2015. To address this issue, a fully interactive model was estimated with an interaction term based on time period introduced into the model. The results of this analysis showed significant differences in the coefficients between time periods. It is not surprising that the coefficients estimated for the first time period were significantly higher than for the second time period. The probability that a given parcel would be built was nearly twice as high in the first time period. The question then arises as to which model is more likely to be a better estimator of construction in the future. Given the nature of the housing bubble, the second period model was deemed more likely to approximate the future.

At this stage in the modeling process, the TAZ variable first had to be constructed which measures activity in the zone 2006-2010. This will be introduced as the lagged variable for the 2011 period. A second issue arose as the production of forecasted construction began. As was noted earlier, it is not only possible but is certain that lots not in existence at the beginning of the period will be built by the end of the new period. In the new time period, the parcels are either classified as lots or they are synthetic lots, lots derived from un-subdivided land at the beginning of the period. The idea of synthetic lots is fundamental to this modeling approach. Synthetic lots can be seen as "potential" lots. The idea of potential and existing lots was described briefly in the preceding section. Each large land area can be subdivided into a number of housing units and that number can be estimated based on what current zoning would allow and the presence of various kinds of development restrictions like flood plains or wetlands. As land develops, large tracts of land called 'PLOTS' in this project are converted to lots and the lots are eventually built to create new housing units. One option considered during the project was to develop two separate models, one for the probability of subdivision of Plots and another for the probability that a lot would be built. This proved to be cumbersome as it required two modeling processes and sets of factors. Also, records needed to be created in any case to hold information for potential lots both in the master modeling table and the GIS layers that would visualize the projections. The modeling process developed in the project is based on the idea that each plot has potential lot records, called synthetic lots, and relative probabilities are modeled for lots and synthetic lots in the same model. This approach proved to be much easier to implement.

In general, one would expect that synthetic lots would be less probable to be built than existing lots. To reflect this new relationship, the variable NOTLOT was created and estimated for the two preceding time periods. A NOTLOT is a parcel that did not exist at the beginning of the period but was either a vacant lot or a built lot at the end of the period. Predictably, being a notlot reduces the probability of being built in both time periods. NOTLOT proved to be a useful variable for 10 and 15 year projections and to adjust the model based on scenarios or information about properties going through the subdivision process with county government. For the projection period all synthetic lots were classified as NOTLOTS.

After constructing the NOTLOT variable the model was re-estimated for both periods. In addition to the introduction of the new variable, one further screen of the parcels to be used in the model was introduced. The parcel at the beginning could only be a not a lot or a lot in 3rd quarter of 2005 and it could only be a lot or built in the fourth quarter of 2010. This excluded any record that was essentially non- existent at the beginning and the end of the period. It also excluded lots that became open space or ag-preservation or any other non-buildable category. This set the parcel base at 19,974 of which 6,210 or 31.1% would be built by 2010.

The analysis introduced other influential independent variables to use in the model. A factor SEWER, was introduced to reflect that the probability of a lot being built was much higher for lots in a sewer district. This factor took the place of a growth area type factor or factor developed from zoning classifications. Another factor was added for those lots that were zoned commercial (LOTC). These were shown to be less likely to be built as a residential lot. A review of the data also showed a set of widely distributed lots that for some reason were not built through time. Some of these "old" lots were very small or were within environmentally restricted areas. A factor CAT90n was introduced and was set to 1 for lots that were lots in 2010 but were also lots in 1990 tax assessment files. The CAT90n lots had some probability of development but it was shown to be less than other lots. An additional variable proved significant: within the New Castle County Assessment file a subdivision name is provided for 97% of the PLOTs. This was seen as an indicator of consideration for subdivision.

Some 38.5% of the parcels were currently in a sewer zone and only 0.8% were classified as commercial. The old lots, (cat90n), accounted for 21.3% of the lots and 96.1% were considered to be in subdivisions. Finally, notlots/synthetic, accounted for 33.7% of the parcels. The model that resulted predicts 76.1% of the lots built status correctly and the Nagelkerke R Square was calculated as .219 or 21.9% of the variance was explained by the model. All of the variables in the model were significant at the 95% level or better and all but one were significant at the 99% level. The positive effects were associated with sewer, being in a subdivision, and being associated with a TAZ that had a higher level of construction activity in the previous five years. The three negative factors included COMLOT, CAT90n, and NOTLOT as predicted. A summary of the factors and form of the model is provided on the next page.

This model is robust by most social science standards although it will be evaluated based on performance in the future. There appear to be distinct improvements over the previous techniques. First, there is no need to allocate units to the CCD before doing the allocation. Second, it is obvious that new units tend to cluster. Third, it more accurately reflects the characteristics of the parcels. It may be interesting to compare the initial period projection at the aggregated modified grid/TAZ level to that developed in the most recent period by modified grid/TAZ.

Summary of Independent Variables

COMLOT – A vacant lot with commercial zoning

CAT90N – Lots in year 2010 that were also lots in 1990. Many of these are lots that for some reason have not been built and in mapping these many are of very small size or are in floodplains or are in otherwise environmentally restricted.

INSUBDIV – New Castle County Tax Assessment files include a variable that lists a subdivision name. This subdivision name is available for any lots in established subdivisions but also is sometimes available for larger tracts of land indicating that it is part of a future plan for subdivision. This factor proved to be significant during the modeling process and could be further examined for accuracy and use in models.

SEWER – A factor indicating whether the lot was within an existing sewer system area. This variable could be altered for a projection time period if it was thought that sewer service was begin extended in parts of the County

NOTLOT – This is a designator for a synthetic lot. Lots that show on current tax parcel maps have a value of zero for this factor, synthetic lots have a value of one. In general an existing lot is expected to have a higher probability for development than one that would be created during a future subdivision of a large land tract.

TAZVAR0610 – Named for the five year period to which the variable refers, this is a traffic zone level factor and is the ratio of the number of properties that were built in the previous five year period in the traffic zone the property is within, to the number of lots that were available in the previous five year period. This is the factor that indicates current building activity.

Specification Of The Model

The probability that a lot will be developed in the first five year period (2011 to 2015) is given as:

$$PROB1115 = \frac{e^{Z}}{(1 + e^{Z})}$$

Where

$$Z = -1.240 + COMLOT * -498 + CAT90n * -1.705 + INSUBDIV * 0.870 + SEWER * -0.307 + NOTLOT * -1.883 + TAXVAR0610 * 1.261$$

This probability was based on the building of 10,172 lots in the 5 year modeling period.

PART Four, Use and Examination of the Model

The section examines the process of using the allocation model to develop a projection for future building of lots.

Step One, Specification of the Model

Part Two of this report explains the development of a model that specifies the probability of lots being built. Given the time available for the research this was the best that could be determined but of course other models are possible that might use other factors. As more information is collected through time, the model could be updated or new models could be developed. The model was built on a database that categorized different types of properties, and developable land is seen as made up of either "Lots" which are actual subdivided single unit tax parcels that are currently visible in tax parcel maps, and as "Synthetic Lots" which are those potential housing units that could be developed from subdivision of larger tracts of land. The independent variables for the model are summarized on the preceding page. The first step is to update or correct all of these factors and to insure that land use classifications are correct.

Step Two, Update of the Master Property Table

The master table includes over 190,000 records for existing properties that are classified as shown in Figure 1. With the time and data available, this project established this classification but certainly there are corrections that could be made and each year classifications change. For instance, updates could be made for lots that are created and built, properties that go from residential to commercial, properties that are classified as undevelopable, or large tracts of land believed to be preserved are subdivided. There are also about 37,800 synthetic lots that were created. Synthetic lots take on the factors (such as SEWER and INSUB) of the parent parcel from which they were made. The model is applied to Lots and Synthetic Lots and the classification needs to best reflect what is known about the availability of properties for development. Working at the very detailed tax parcel level involves a continuous and detailed update process. This is facilitated greatly by GIS, and continuous involvement of a number of sources for the information. Classifications of properties and model factors need to be updated in the master property table each time a projection is run. The factors used in the model also need to be updated. If sewer service has been extended or expected to be extended in the future, then data for properties that are newly within services areas needs to be updated. Building activity in the prior five years and any new information that appears in the model factors need to be updated.

Step Three, Calculate modeled probabilities to be built and adjust probabilities based on expected growth

The probability that a lot or synthetic lot will be built is calculated by the model as

z1115 = -1.240 + COMLOT * -498 + CAT90n * -1.705 + INSUBDIV * 0.870 + sewer * 0.307 + NOTLOT *-1.883 + blto610 * 1.261.

prob1115=exp(z1115)/(1+exp(z1115)).

This is calculated for Lots and Synthetic Lots in 2010. As the model was built on five years of data where 10172 properties were built, the sum of the probabilities will equal 10,172. However if we are looking at the period between 2011 and 2015, the Delaware Population Consortium estimates that in New Castle County, 9,550 will be added/built so the probabilities to use for the 2011 to 2015 forecast will need to be adjusted to this control total. As less lots are being built, the probability of lots being built is slightly less.

Prob1115adj = Prob1115 * 9550 / 10172

Step Four, Selecting what lots will be built in the selected time period

To project what lots to select as built, the lots with the highest probability would be selected and this would be the best guess even though it is known that properties with a smaller probability of being built as specified by the model will be seen as built once we obtain the actual data for the time interval in the future. Selecting where lots will be built in this first stage for the year 2011 to 2015 projection period comes down to selecting the top 9550 lots (number of housing units projected from DPC) from a list ranked by highest probability.

Step Five, Examining Results

SPSS statistical software was used to do modeling and data table calculations in this project but other programs that work with tabular data would work. The master table including probability calculations, was exported in a DBASE format and added to ArcMap which was the GIS platform used for the project. The current tax parcel polygon layer and the synthetic lots point file were both joined to the master table with probabilities and a thematic map was created to show the distribution of the modeled probabilities for lots being built. As the calculations are very straightforward, master tables could be manipulated in GIS software such as ArcMap without the use of other software to manipulate tables. Maps of the resulting probabilities follow. The map layers shown and the master table are all in the project data collection for more detailed review. Tax parcels with no color are either built residential lots or non-residential.

The points are synthetic lots representing potential development and are colored by their estimated probability for becoming built lots. The number of synthetic lots in each large tax parcel are within is the number estimated that can be supported by current zoning.

If a selection was made of the most probable 9550 that would become lots, then those properties would be greater than a .46 probability. These are shown in orange or red in the maps. The highest probability for synthetic lots for this five year estimate was 0.24 and none would be selected for being built.

Figure 28, Lots projected to be built between 2011 and 2015 (shown in orange)

Figure 29, Distribution of Probabilities for Lot Construction in 2011 to 2015 with Synthetic Lots (points) included. Below and above the C&D Canal in New Castle County, (orange are projected lots to be built)

Step Six, Adjustments

Various adjustments can be made to the base data. Each year there is new information, and factors and property classifications can change. Putting the data together for New Castle County in this project was a very time consuming effort and serves as a good start, but certainly there is a great deal of other information about properties at these tax parcel layers. Specific information will come to light from various sources that certain properties may have new or corrected classifications or have a much lower or much higher probability of development. New information can be added to make better predictions. Planners also are frequently involved in scenario analysis and will be interested in what future development patterns may take place in the future if a certain large scale development takes place or is encouraged in various parts of the county, and classifications, factors, and probabilities could be adjusted and new projections made. Probabilities of development in a particular projection period could be forced to lower or higher probabilities (like 1.0) to study effects. Use of GIS can greatly facilitate update of the model and examination of scenarios.

New Castle County government tracks development activity through the subdivision process, and this is a very good source of information for what will be coming in the future, and an adjustment that would be desirable to incorporate. This is a simple but important example. Figure 30 shows large tracts of land outlined in pink that are currently listing as places where there is a subdivision plan “PENDING” approval in the New Castle County. This represents close to thousands of new lots that have a high probability of being added in the next few years. Figure 31 also on the next page shows synthetic points and their probabilities, some of which are higher assuming subdivision plans were approved.

The following developments are listed as pending subdivisions:

Development Name	**Lots**
Spring Oaks	242
Carter Farm	36
Deats Farm	1381
Church Town	73
Village of Scott Run	273
Ashby’s Place	54
Boyds Corner Farm	287
High Hook Farms	390
Wilchelsea	618
Windsor Commons at Hyetts	316
Lightkkkk	54
Port Penn Assemblage	505
Wrnkkk Tract	143
Oasis at Cypress Ridge	29

The subdivision activity data was a few months older than the November 31, 2010 version of the tax parcel map. Some of these had been approved and lots are shown within and are expected to be developed in the first five year projection period.

Figure 30, Properties Shown as "PENDING" in New Castle County Development Activity Process (shown outlined in pink)

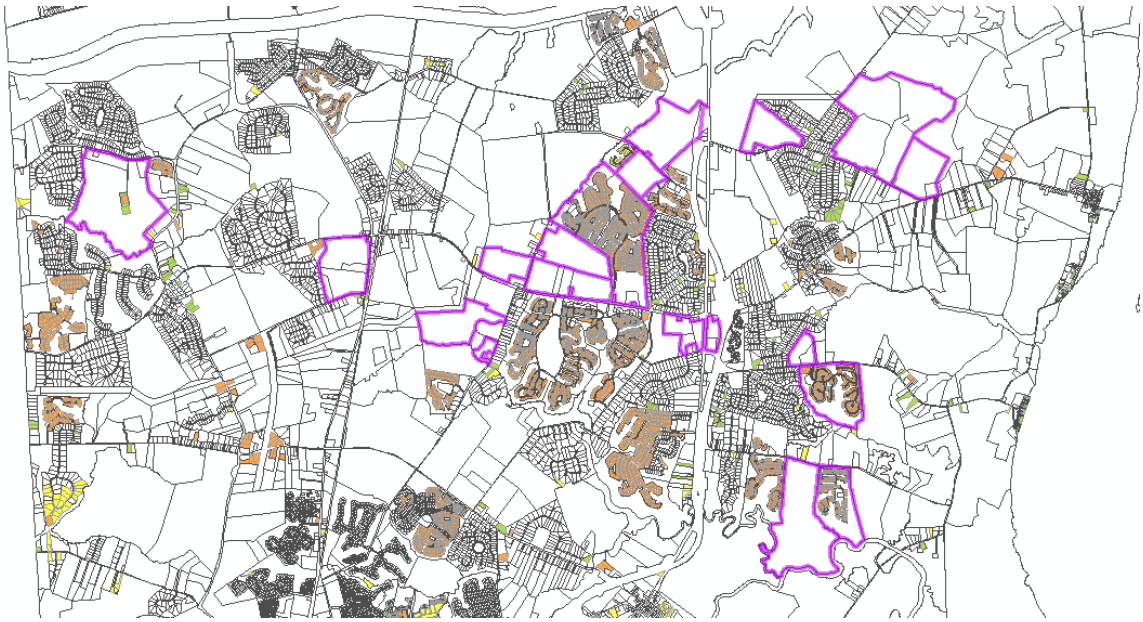


Figure 31, PENDING Subdivisions (outlined in pink) Shown With Lots and Synthetic Lots, Before Adjusting for Pending Subdivision Activity

An update to the data would take into account the additional information known about subdivision activity and would involve first adjusting the number of synthetic lots currently estimated for the property to match the lots listed in the subdivision plan. The master table would be edited to add or delete synthetic parcel records and the GIS point file would be also edited to add or delete synthetic parcels. The inclusion of the factor NOTLOT in the model facilitates this kind of adjustment. As indicated before, NOTLOT is a factor that takes into account that a property that is an existing approved lot has roughly four times the probability of being built in five year period than a lot that would have to be created as part of a subdivision process and then built. Synthetic lots have a value of 1 for the NOTLOT factor. Changing this value to zero for the PENDING areas is expected to produce the desired adjustment. Figure 32 below shows how probabilities for synthetic lots have increased when compared to Figure 31on the previous page. Increased probabilities based on the knowledge of subdivision activity would project some synthetic lots to be built in the first five year projection period.

A similar adjustment could be made to examine various scenarios that look at the effect of large amounts of development in a particular area. Factors for synthetic lots could be changed through the NOTLOT and INSUBDIV values. New sewer service projected for currently unserved areas could be modeled by changing the SEWER factor. It is also possible to assign a probability of 1 to any lot to insure it is built in a projection period of interest. Part of the power of a tax parcel based approach is to be able to track and take advantage of detailed property level information. A careful review of the data each year and updates of categorizations could show improvements in estimates.

Figure 32, Probabilities for Development of Lots and Synthetic Lots Taking Into Account Pending Subdivision Activity, Synthetic Lots in Orange Now Projected To Be Built in 2011 to 2015

Ten Year Projections – Strict Application of the Model

The previous discussion showed how we can use the logistic regression to estimate the odds that one parcel becomes developed relative to another. Because we assume that these relative probabilities remain fixed over five years, they can be scaled to reflect how much the assumed amount of development that would occur in the next five years. This allows us to forecast which parcels are more likely to be developed in the next five years. In the following discussion, we briefly sketch out how such a model could be iterated so that the five year forecast is used to make predictions for the ten year forecast.[1]

There are four steps in this iteration:

1. The analyst must predict the total amount of development that can be expected to occur between time periods t+6 and t+10.
2. The predicted amount of development between time periods t+1 and t+5 are used to update our expectations about the future characteristics of each parcel.
3. The expected future characteristics interact with the model's estimated parameters so that a new set of relative probabilities are created.
4. The new set of relative probabilities is scaled to reflect the total development that is assumed to occur between time periods t+1 and t+10.

The first step requires that an analyst use aggregate projections from outside sources to determine the total development that will occur in the future. Such projections might rely on demographic or macroeconomic forecasts. The projections could also come from scenario analyses. This is provided by Delaware Population Consortium estimates.

The second step uses the 2015 predictions to update the expected value of each variable. Six variables are updated based on the 2015 predictions: NOTLOT, INSUBDIV, CAT90, TAZVAR, COMLOT, and SEWER.

The NOTLOT variable needs to be updated because it indicates which parcels become lots, and therefore indicates that they are ready for development. However, as development occurs, properties that were not lots have a chance of becoming lots in the future. In fact, parcels that are most likely to be developed, are also likely to become lots.

The INSUBDIV variable indicates that an undeveloped property is planned to be turned into a subdivision. However, properties that are more likely to develop are also more

[1] We caution the reader that the model was designed for a five year-ahead forecast. Iterating this model necessarily compounds the forecast error. This reflects the fact that the greater extrapolation yields greater error.

likely to be given a subdivision name. This is similar to our reasoning behind updating the NOTLOT variable.

The CAT90 variable indicates which undeveloped properties were lots ready to be developed in 1990. Though less likely, some of these properties will be developed so CAT90 needs to be adjusted.

The TAZVAR indicates which other properties in a particular traffic analysis zone (TAZ) are developed. If we have estimates on which properties will likely be developed, then we would also have estimates on how many properties develop in a TAZ. Thus, this variable also requires updating based on our model results.

The SEWER and COMLOT variables are mostly controlled by policy makers. We have no prior beliefs as to how development will change the sewer districting and commercial zoning. Therefore, these variables do not change in the updates. Specific assumptions and details for each variable are made in an appendix.

To proceed with this estimate, we relied on our model parameters one more time so that we could estimate a new set of relative probabilities. This new set of probabilities was normalized to reflect chances that the property would be developed in between 2016 and 2020. Finally, we combined these new estimates with the probability that a property was developed between 2011 and 2015 to yield the ten year forecast. Details of this procedure are given in the appendix.

A map of probabilities for showing a 10 year projection is shown on the next page and are similar to what was provided in other methods discussed next. Estimating the probabilities and future independent variables is an involved process and more involved going out 20 or 30 years. It is suspected that algorithms could be developed for 20 or 30 year projections with this more rigorous approach to the calculation. In practice without such algorithms the calculation could be difficult.

Ten Year Projection – 5 year model on 10 year projection number

Another approach to extend the model would be to use the five year factors but apply a control total of housing units to be added that included 10 years of projected growth. This provides a simple means to extend the forecast past five years. For instance Delaware Population Consortium Figures estimate county housing units to be added in the period of years 2010 to 2005 to be 9550. In the period between 2010 to 2020, 17789 housing units are projected to be added to New Castle County. If about 17789 housing units are selected to be built from most probable lots and synthetic lots in the master table the picture would as shown in figure 34. The calculation of probabilities in that figure includes the adjustment for PENDING subdivision.

Figure 33, Probability Distribution For A 10 Year Projection Involving Re-estimation of Factors From Analysis of Probabilities.
(Polygons and points in orange and red projected to be built. Does not take into account pending subdivision.)

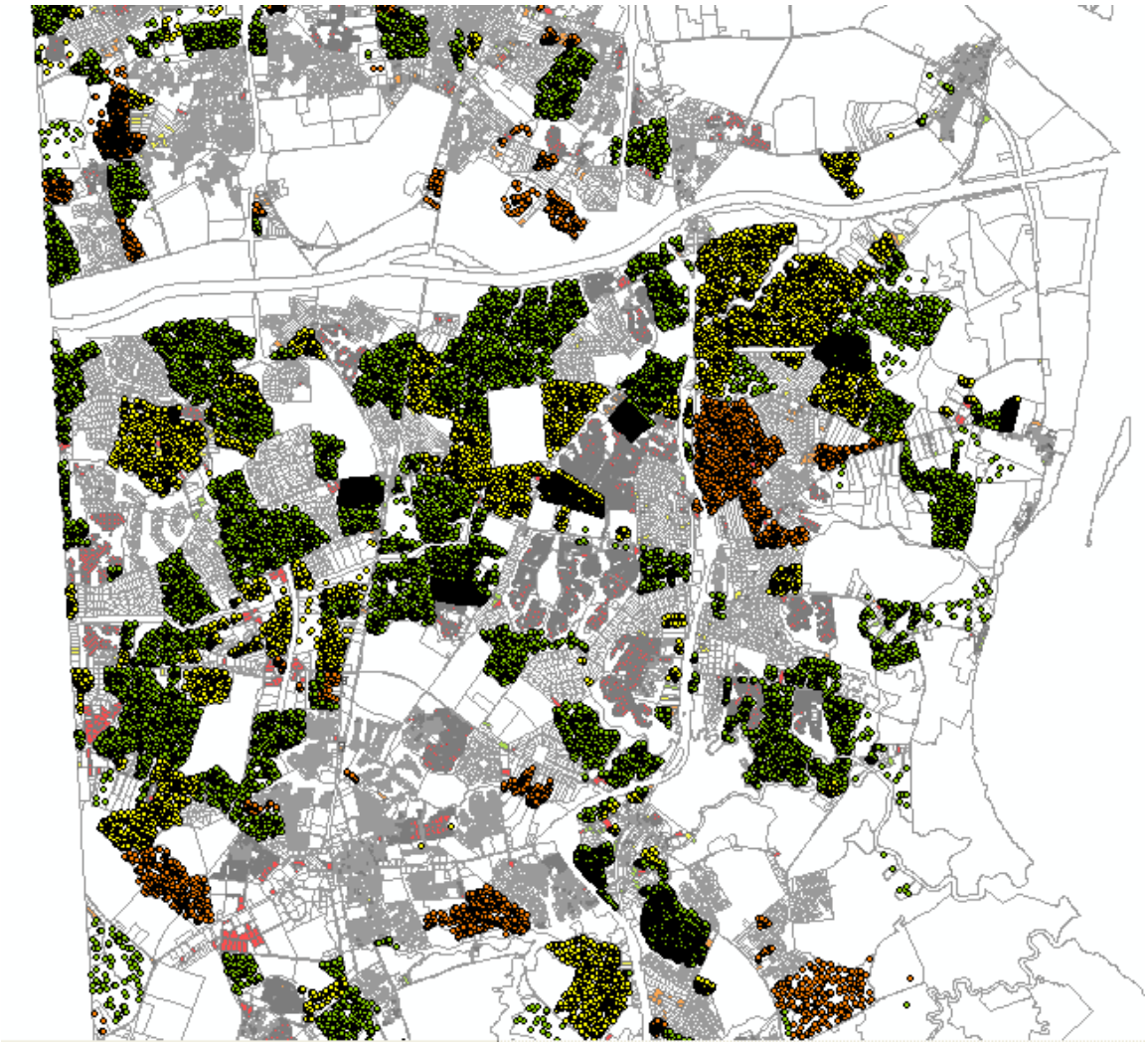


Figure 34, 10 year projection (2011 to 2020) produced by 10 year DPC projection on 5 year model
Orange and Red lots are expected to be built (Red – probability 0.4 to 0.67, Orange 0.15 to 0.4, Yellow 0.01 to 0.10)

Ten Year Projection – Removing Modeled Built Properties, Recalculating Factors and Applying Model

Another approach to the ten year or more forecast using the model would be to assume the projected housing units for the initial five year period are built and then remove them from consideration for the next five year period by reclassifying them as built, and then recalculate factors and re-estimate probabilities for the next five year period based on the assumption that they were built. This would have the advantage of a re-estimation of the traffic zone activity variable and does not involve a recalculation of factors based on a probability analysis. Time available for this project did not allow for examination of this approach, but it seems promising particularly for a 15 year projection. The first 10 years of any projection methodology is expected to be dominated by existing lots and pending subdivision activity. The first 10 years could be projected thru a rigorous application of the model involving algorithyms taking into account a study of the probabilities of factors, or for simplicity, applying 10 year growth totals to the five year model. Once there was a 10 year projection, the projected 10 year growth could be assumed and properties selected as built could be removed a factors for remaining developable land could be calculated in an easier fashion. It is as if the process is starting over from the beginning after the first 10 year projection.

Comparison of Model Projection with Currently Used Traffic Zone Allocations

With an expected improved accuracy resulting from building the model from more specific data at the tax parcel level, it is thought that these new models would be an improvement to methodologies used in the past. A more thorough construction of projections and a study of results is needed. It is interesting to make a comparison with current projections for the first 10 years. A five year and 10 year projection was generated using the project model after first taking into account pending subdivision activity. The number of housing units per traffic zone between year 2020 generated from the model was subtracted from the difference in the number of housing units between years 2020 and 2010 for the current projections and is mapped in Figure 35. Big negative numbers in dark green are areas where the model projected more growth. The map shows the model putting more construction below the canal than the current methodologies. The bottom five of these ranging from -525 to -245 were investigated and it seems that pending developments* were not taken into account in the current methodologies. The current method shows in red a few traffic zones where there were 300 or more new lots built as compared to the modeled projection. Discussion with county land use planners referenced specific development activity not tabulated in this projects master table. Having the GIS mapping allows for study of particular results and maps for Traffic Zone 178, Traffic Zone 212, Traffic Zone 113, and Traffic Zone 340 are provided as examples in Figures 38 thru 41 .

* Bayberry North, Port Penn Assemblage, Boyds Corner Farm, Carter Farm, and High Hock Farms

FIGURE 35 Comparison of Model Projection for 2020 Compared to Current Traffic Zone Projections. MODEL minus CURRENT

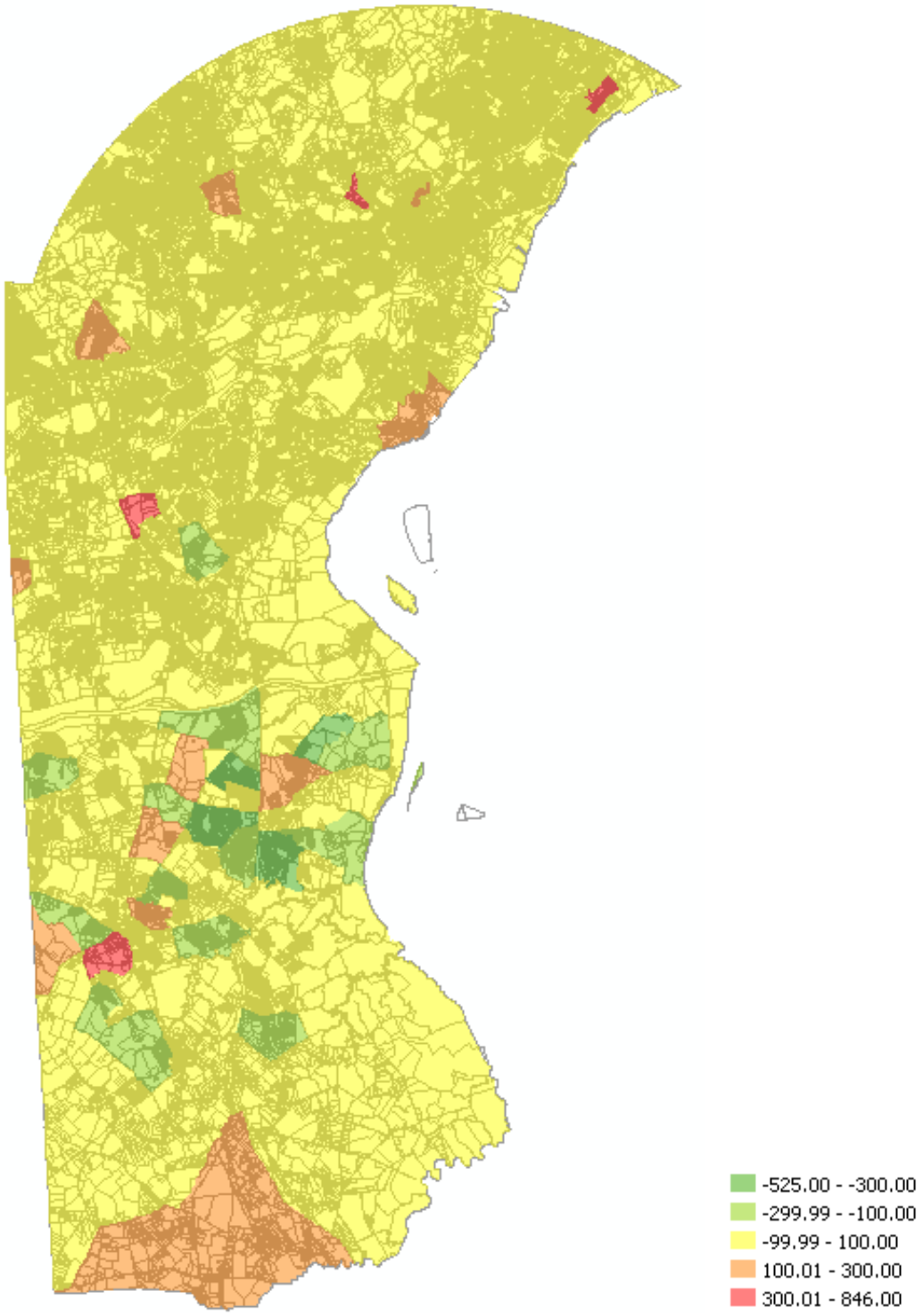


Figure 36, Projection Comparison by Traffic Zone of Current Allocation with Project Model Allocation, Records Showing Model Estimating More Construction (model preceded by "m", current preceded by "w"

taz	tazn	m2010	m2015	m2020	w2010	w2015	w2020	df10to20	
332	332	.	.	.	0	0	0	.	
335	335	.	.	.	0	0	0	.	
341	341	.	.	.	105	108	110	.	
280	280	82	82	1245	77	420	715	-525.00	bayberry north, windsor commons at hyett
284	284	82	82	749	78	213	344	-401.00	Port Penn Assemblage
274	274	52	697	1187	52	317	813	-374.00	Boyds corner farm
321	321	332	882	885	318	422	538	-333.00	High Hock Farms
193	193	225	763	769	221	331	491	-274.00	Carter Farm
197	197	887	1025	1220	902	952	990	-245.00	synthetic lots modeled to be built
192	192	237	565	567	219	283	349	-200.00	
191	191	435	763	764	531	597	663	-197.00	
194	194	248	711	711	237	350	506	-194.00	
302	302	416	829	829	394	505	620	-187.00	
195	195	29	29	261	32	57	82	-182.00	
190	190	185	609	614	180	303	429	-180.00	

Figure 37, Projection Comparison by Traffic Zone of Current Allocation with Project Model Allocation, Records Showing Model Estimating Less Construction (model preceded by "m", current preceded by "w"

taz	tazn	m2010	m2015	m2020	w2010	w2015	w2020	df10to20
216	216	16	16	95	23	127	253	151.00
316	316	481	481	484	478	590	667	186.00
314	314	14	14	132	13	200	398	267.00
210	210	772	814	1006	978	1293	1481	269.00
339	339	314	314	592	350	626	916	288.00
340	340	6	6	6	75	219	381	306.00
212	212	1	1	2	2	169	330	327.00
178	178	91	91	92	256	456	656	399.00
113	113	785	818	825	776	1383	1662	846.00

Figure 38, Land Use in Traffic Zone 170

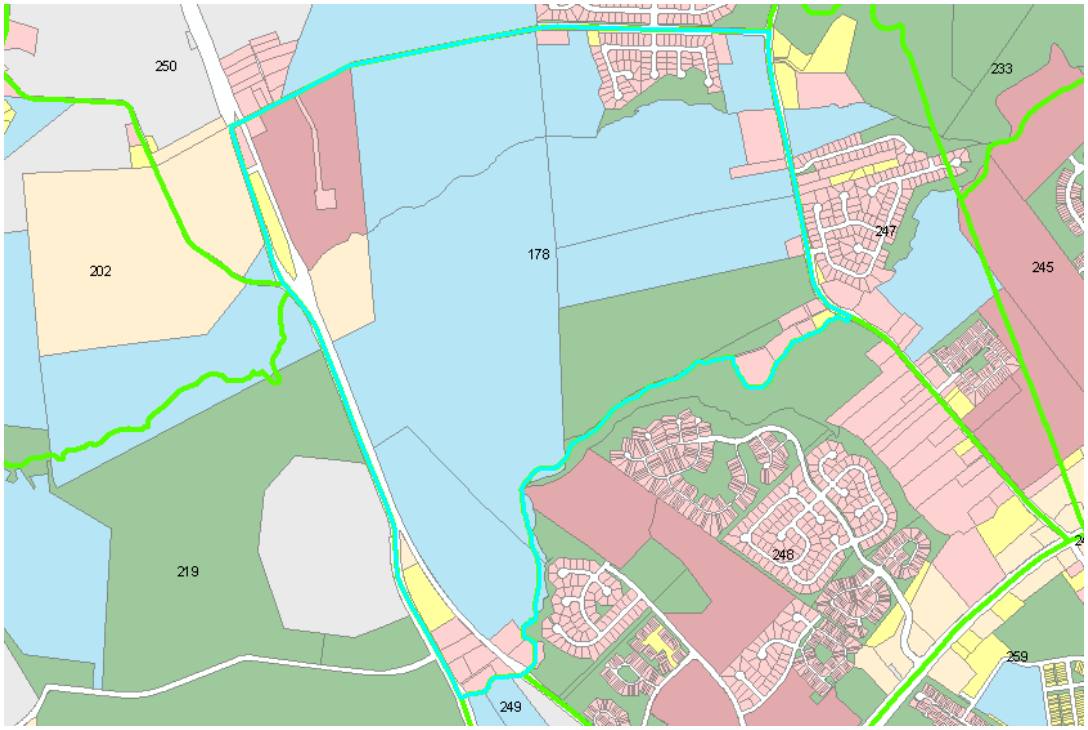


Figure 39, Land Use in Traffic Zone 212

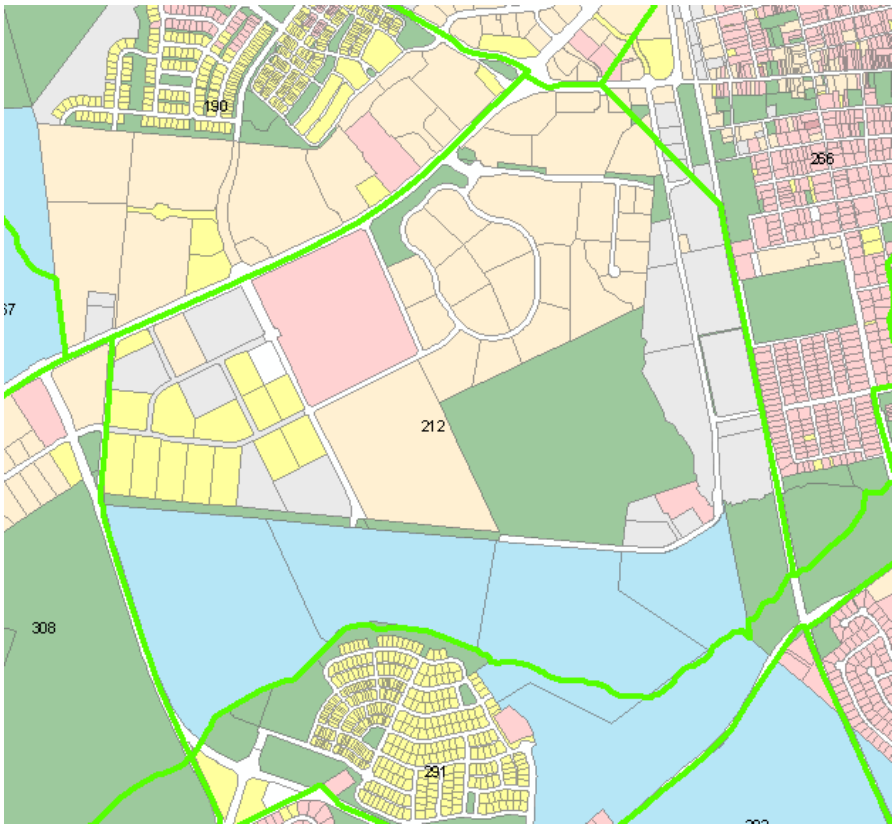


Figure 40, Land Use in Traffic Zone 113

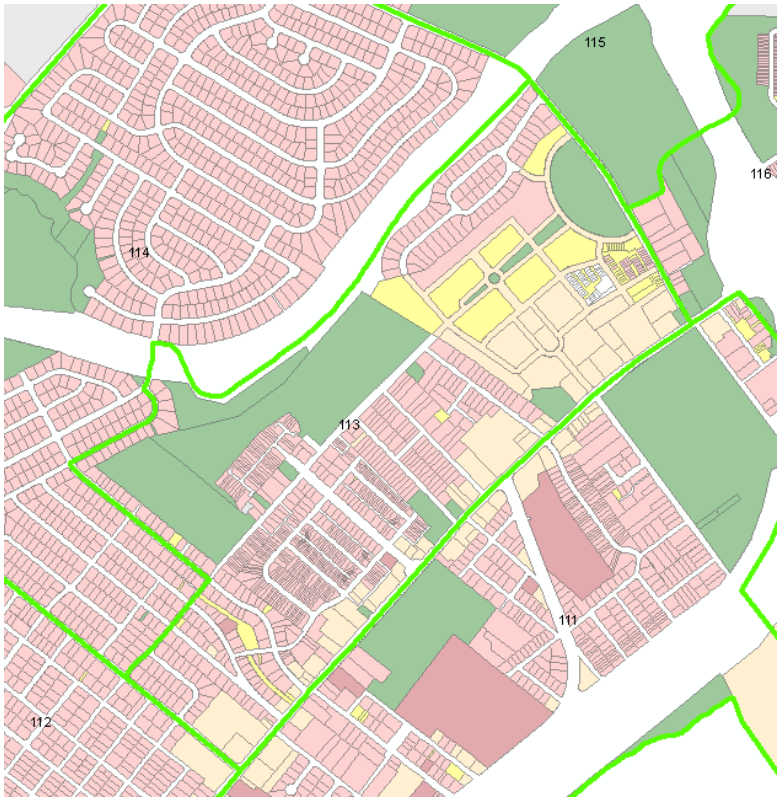
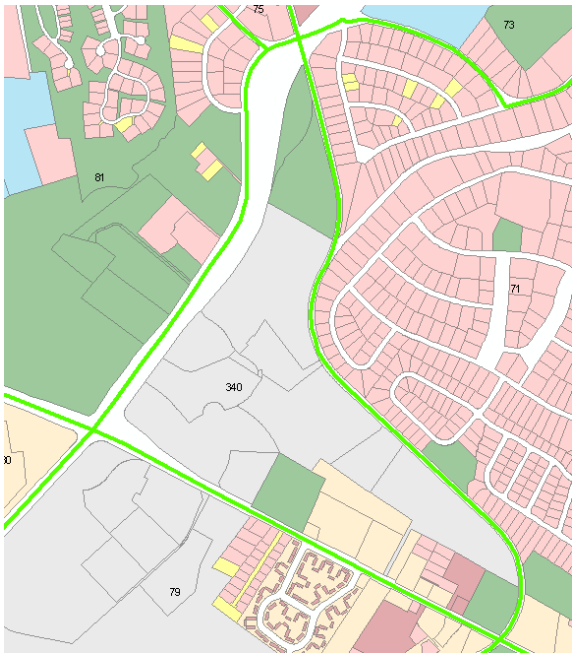


Figure 41, Land Use in Traffic Zone 330



Part Five, Going Forward and Conclusions

Travel demand forecasting and land use tracking has moved to the very detailed tax parcel level and there is a need to have a resource that planners can work with. The tax parcel maps together with the master categorization and modeling table provide a powerful framework to capture data at this detailed level. There was a large effort to compile the base data that serves as a good starting point for future efforts.

There are some advantages to the model presented over current practices:

* Much more detailed data and views to examine projections and drivers of growth are available.
* Avoidance of steps that depend first on projections at the Planning District Level
* The modeling process developed is more easily understood, modified, and implemented by Planners. Examination of growth scenarios is much easier to understand and implement.
* At the tax parcel level there are more possibilities to integrate information with other data sets across purposes. There is a large amount of addressed based land use information that can be incorporated.
* Once projections are developed they are reviewed by several agencies and individuals and through various types of collaboration adjustments are made. This detailed level assists in making adjustments that can be more easily visualized and justified.
* the model deals only with residential land uses, but the overall data structure could support analysis and tracking of commercial uses, employment, and trip attractors.

The best test of the model is to examine how it performs through time as data is updated from year to year. Perhaps other useful factors could be discovered to incorporate into the model. Other next steps for a better model include:

* Review and update of all land use classifications and model factors.
* Further development of methods for associating information with land use at the tax parcel level.
* Addressing multi-family housing better. The data includes location of multi-family housing in 2010 but does not model its creation in projections. With the down turn in the economy, some indications are that more multifamily housing will be created in the future and there could be significant effects that have not been considered.
* The model does not deal with vacancy information but the datasets and modeling procedures could take advantage of vacancy classifications.
* the model does not work with reconstruction of the housing base, perhaps there would be some usefulness in examining this.
* the modeling process for 15, 20, and longer term projections could be facilitated by developing algorithms for estimating future factors in a way that is more true to the probabilities and expectations in the model. Initial indications are that it might be possible within a reasonable amount of effort to automate the projection process.

Appendix

Comparison of Model and Current Traffic Zone Projections
Model includes Pending development, Current 2/1/2011 Projections from WILMAPCO
TAZ=Traffic Zone M10 = Model 2010 M15=Model 2015 M20=Model 2020
W10 = Current Projections 2010 W15 – Current 2015 W20- Current 2020

TAZ	M10	M15	M20	W10	W15	W20	(W20 – W10) – (H20 – H10)
1				87	87	87	
2	1	1	1	279	279	279	.0
3	36	36	38	150	150	150	-2.00
4	5	5	5	142	146	150	8.00
5				1	1	1	
6	65	65	65	308	310	312	4.00
7	6	6	6	26	26	26	.0
8				33	33	33	
9				28	33	38	
10				12	12	12	
11	11	11	17	9	9	9	-6.00
12	186	186	186	226	226	226	.0
13	1	1	1	59	59	59	.0
14	513	523	523	786	786	786	-10.00
15	333	333	339	566	566	566	-6.00
16	1117	1131	1170	1142	1149	1156	-39.00
17	223	231	235	165	170	175	-2.00
18	775	795	811	897	907	916	-17.00
19	85	85	86	490	490	490	-1.00
20	1152	1163	1163	1323	1323	1323	-11.00
21	506	507	512	776	776	776	-6.00
22	339	339	344	611	611	611	-5.00
23	1113	1130	1130	1221	1221	1221	-17.00
24	1068	1072	1082	1201	1201	1201	-14.00
25	511	511	511	536	536	536	.0
26	258	258	261	479	479	479	-3.00
27	536	536	537	2383	2383	2383	-1.00
28	719	723	723	827	961	971	140.00
29	317	317	320	310	319	329	16.00
30	579	582	582	791	791	791	-3.00
31	114	117	117	114	114	114	-3.00
32	225	225	232	678	678	679	-6.00
33	921	939	939	1400	1408	1417	-1.00
34	450	450	452	634	634	634	-2.00
35	548	549	555	1065	1068	1069	-3.00
36	894	897	914	921	921	921	-20.00
37	760	771	771	928	931	934	-5.00
38	915	927	931	1093	1094	1094	-15.00

Comparison of Model and Current Traffic Zone Projections
Model includes Pending development, Current 2/1/2011 Projections from WILMAPCO
TAZ=Traffic Zone M10 = Model 2010 M15=Model 2015 M20=Model 2020
W10 = Current Projections 2010 W15 – Current 2015 W20- Current 2020

TAZ	M10	M15	M20	W10	W15	W20	(W20 – W10) – (H20 – H10)
39	752	752	758	1075	1130	1135	54.00
40	1344	1350	1350	1333	1333	1333	-6.00
41	1112	1112	1119	1268	1275	1281	6.00
42	63	63	63	147	188	192	45.00
43	216	231	231	319	328	338	4.00
44	208	208	211	169	170	172	.0
45	0	0	1	0	0	0	-1.00
46				0	0	0	
47	842	842	856	785	785	785	-14.00
48	604	613	613	1408	1411	1414	-3.00
49	47	47	52	209	210	211	-3.00
50				0	113	116	
51	18	18	20	16	19	21	3.00
52	1	1	1	0	0	0	.0
53				0	0	0	
54	138	139	139	1441	1485	1518	76.00
55	546	551	553	780	793	806	19.00
56	1415	1423	1424	1707	1708	1710	-6.00
57	234	234	236	921	921	922	-1.00
58	495	496	496	474	474	474	-1.00
59	425	427	427	410	410	410	-2.00
60	592	599	599	717	718	718	-6.00
61	8	12	14	70	71	72	-4.00
62	254	256	256	452	452	452	-2.00
63	1094	1101	1101	1343	1355	1366	16.00
64	1128	1134	1135	1089	1090	1090	-6.00
65	845	847	847	809	810	810	-1.00
66	1252	1257	1257	1203	1210	1217	9.00
67	1090	1090	1091	1187	1188	1188	.0
68	1151	1164	1184	1172	1179	1185	-20.00
69	158	158	158	152	152	153	1.00
70	908	963	965	890	917	945	-2.00
71	452	459	459	443	443	443	-7.00
72	28	28	29	36	40	44	7.00
73	9	9	9	627	647	667	40.00
74	162	166	168	174	176	177	-3.00
75	272	274	281	272	276	279	-2.00
76	105	106	107	265	269	274	7.00
77	71	71	73	80	81	83	1.00

Comparison of Model and Current Traffic Zone Projections
Model includes Pending development, Current 2/1/2011 Projections from WILMAPCO
TAZ=Traffic Zone M10 = Model 2010 M15=Model 2015 M20=Model 2020
W10 = Current Projections 2010 W15 – Current 2015 W20- Current 2020

TAZ	M10	M15	M20	W10	W15	W20	(W20 – W10) – (H20 – H10)
78	504	508	513	502	504	505	-6.00
79	29	29	29	506	506	506	.0
80	373	377	377	356	361	365	5.00
81	338	359	360	338	338	339	-21.00
82	436	473	473	418	446	471	16.00
83	1221	1229	1230	1206	1215	1220	5.00
84	781	783	794	779	780	781	-11.00
85	763	763	764	736	737	737	.0
86	414	424	424	401	401	402	-9.00
87	118	119	120	121	122	123	.0
88	565	571	582	801	802	802	-16.00
89	263	270	272	432	441	450	9.00
90	591	591	591	705	706	708	3.00
91				0	0	0	
92	786	787	789	1460	1462	1463	.0
93	1388	1399	1399	1684	1688	1691	-4.00
94	343	343	344	333	334	335	1.00
95	1012	1012	1012	1034	1034	1035	1.00
96	576	585	586	600	606	612	2.00
97	228	242	242	238	238	239	-13.00
98	593	594	601	639	639	639	-8.00
99	735	744	744	1027	1027	1028	-8.00
100	207	220	221	199	203	208	-5.00
101	1023	1055	1061	995	1003	1015	-18.00
102	1081	1086	1091	1046	1052	1062	6.00
103	239	251	264	230	230	230	-25.00
104	739	739	745	708	708	708	-6.00
105	803	812	834	853	853	853	-31.00
106	2038	2045	2045	2212	2212	2212	-7.00
107	1255	1255	1261	1321	1325	1328	1.00
108	1397	1400	1401	1791	1791	1791	-4.00
109	1708	1755	1755	1771	1827	1919	101.00
110	647	647	647	692	692	692	.0
111	654	656	669	1663	1663	1663	-15.00
112	865	866	872	1298	1298	1298	-7.00
113	785	818	825	776	1383	1662	846.00
114	1109	1109	1109	1065	1065	1065	.0
115	259	259	262	1932	1938	1944	9.00
116	326	345	345	331	333	334	-16.00

Comparison of Model and Current Traffic Zone Projections
Model includes Pending development, Current 2/1/2011 Projections from WILMAPCO
TAZ=Traffic Zone M10 = Model 2010 M15=Model 2015 M20=Model 2020
W10 = Current Projections 2010 W15 – Current 2015 W20- Current 2020

TAZ	M10	M15	M20	W10	W15	W20	(W20 – W10) – (H20 – H10)
117	34	34	34	133	152	171	38.00
118	574	578	578	860	860	860	-4.00
119	1234	1242	1247	1185	1187	1188	-10.00
120	1007	1008	1008	1035	1037	1038	2.00
121	814	816	816	803	815	826	21.00
122	886	891	892	856	860	863	1.00
123	688	690	690	746	755	764	16.00
124	650	651	651	889	893	896	6.00
125	1124	1128	1131	2139	2139	2139	-7.00
126	933	937	937	960	963	967	3.00
127	219	219	240	237	267	296	38.00
128	83	83	84	96	100	104	7.00
129	95	95	104	108	112	115	-2.00
130	128	129	130	139	141	143	2.00
131	252	252	265	264	266	267	-10.00
132	145	145	146	155	156	158	2.00
133	222	379	379	213	261	296	-74.00
134	599	600	600	581	598	614	32.00
135	360	360	362	457	474	490	31.00
136	613	619	619	600	604	607	1.00
137	1649	1665	1672	1610	1614	1619	-14.00
138	1087	1094	1102	1067	1072	1077	-5.00
139	1586	1588	1589	2110	2117	2124	11.00
140	1433	1441	1448	1621	1626	1631	-5.00
141	1536	1536	1536	1925	1930	1935	10.00
142	1449	1463	1464	2919	2924	2929	-5.00
143	2298	2394	2409	2703	2741	2770	-44.00
144	2848	2963	2984	3125	3157	3186	-75.00
145	1034	1040	1042	1763	1764	1765	-6.00
146	1876	1877	1879	3089	3094	3100	8.00
147	2612	2733	2736	2596	2649	2689	-31.00
148	1176	1191	1199	1472	1562	1602	107.00
149	13	13	13	13	13	13	.0
150	183	183	183	1144	1144	1144	.0
151	36	36	36	35	35	35	.0
152	1482	1482	1495	2597	2597	2597	-13.00
153	562	619	619	815	833	858	-14.00
154	1288	1289	1289	2194	2194	2194	-1.00
155	762	762	762	740	741	742	2.00

Comparison of Model and Current Traffic Zone Projections
Model includes Pending development, Current 2/1/2011 Projections from WILMAPCO
TAZ=Traffic Zone M10 = Model 2010 M15=Model 2015 M20=Model 2020
W10 = Current Projections 2010 W15 – Current 2015 W20- Current 2020

TAZ	M10	M15	M20	W10	W15	W20	(W20 – W10) – (H20 – H10)
156	60	60	62	72	73	75	1.00
157	681	683	684	714	716	717	.0
158	1875	1875	1875	3718	3745	3762	44.00
159	4	4	5	5	5	5	-1.00
160	1	1	1	0	0	0	.0
161	311	311	578	305	421	537	-35.00
162	524	525	525	596	601	606	9.00
163	1786	1798	1799	3536	3543	3549	.0
164	1461	1496	1496	2079	2112	2146	32.00
165	6	6	6	13	15	16	3.00
166	533	538	616	582	586	589	-76.00
167	1368	1454	1455	2299	2346	2414	28.00
168	260	263	264	703	706	709	2.00
169	311	315	315	518	519	521	-1.00
170	107	107	107	111	112	114	3.00
171	748	751	751	1002	1010	1023	18.00
172	1017	1019	1020	1353	1358	1363	7.00
173	618	620	624	681	709	744	57.00
174	18	81	84	317	358	406	23.00
175	1132	1139	1139	1217	1232	1245	21.00
176	679	682	693	664	669	674	-4.00
177	116	116	116	112	113	115	3.00
178	91	91	92	256	456	656	399.00
179	582	652	656	581	625	656	1.00
180	970	972	973	2677	2684	2691	11.00
181	563	565	569	552	588	618	60.00
182	733	754	754	717	742	767	29.00
183	335	336	337	325	340	358	31.00
184				1	8	14	
185	294	294	294	281	285	290	9.00
186	238	270	367	223	244	275	-77.00
187	3	3	3	3	3	3	.0
188	652	668	677	707	710	713	-19.00
189	298	298	300	285	294	300	13.00
190	185	609	614	180	303	429	-180.00
191	435	763	764	531	597	663	-197.00
192	237	565	567	219	283	349	-200.00
193	225	763	769	221	331	491	-274.00
194	248	711	711	237	350	506	-194.00

Comparison of Model and Current Traffic Zone Projections
Model includes Pending development, Current 2/1/2011 Projections from WILMAPCO
TAZ=Traffic Zone M10 = Model 2010 M15=Model 2015 M20=Model 2020
W10 = Current Projections 2010 W15 – Current 2015 W20- Current 2020

TAZ	M10	M15	M20	W10	W15	W20	(W20 – W10) – (H20 – H10)
195	29	29	261	32	57	82	-182.00
196	278	278	313	341	378	410	34.00
197	887	1025	1220	902	952	990	-245.00
198	101	101	105	111	124	136	21.00
199	468	468	468	451	495	533	82.00
200	322	322	334	431	465	493	50.00
201	89	89	89	109	139	167	58.00
202	7	7	25	13	23	33	2.00
203	99	99	171	104	139	170	-6.00
204				0	0	0	
205	76	77	80	75	75	75	-4.00
206	901	922	922	879	882	885	-15.00
207	232	232	465	225	306	387	-71.00
208	1110	1112	1112	1079	1082	1085	4.00
209	796	1019	1019	794	848	920	-97.00
210	772	814	1006	978	1293	1481	269.00
211	1185	1205	1210	1484	1525	1548	39.00
212	1	1	2	2	169	330	327.00
213	353	399	400	342	357	369	-20.00
214	66	66	70	71	116	160	85.00
215	154	154	156	145	162	176	29.00
216	16	16	95	23	127	253	151.00
217	156	156	159	152	163	172	17.00
218	112	112	112	105	128	149	44.00
219	126	126	128	122	124	126	2.00
220	403	464	467	392	400	409	-47.00
221	849	851	855	849	851	853	-2.00
222	119	119	122	113	115	116	.0
223				0	0	0	
224				0	27	50	
225	35	63	64	36	40	43	-22.00
226				0	0	0	
227				0	0	0	
228				0	0	0	
229				0	0	0	
230	917	921	924	1515	1539	1550	28.00
231	77	77	78	80	81	81	.0
232	406	435	439	871	876	882	-22.00
233	1656	1658	1658	1605	1605	1605	-2.00

Comparison of Model and Current Traffic Zone Projections
Model includes Pending development, Current 2/1/2011 Projections from WILMAPCO
TAZ=Traffic Zone M10 = Model 2010 M15=Model 2015 M20=Model 2020
W10 = Current Projections 2010 W15 – Current 2015 W20- Current 2020

TAZ	M10	M15	M20	W10	W15	W20	(W20 – W10) – (H20 – H10)
234	1204	1232	1237	2142	2146	2150	-25.00
235	390	391	391	369	369	369	-1.00
236	831	831	833	814	824	839	23.00
237	505	505	505	1458	1458	1459	1.00
238	74	77	84	73	80	88	5.00
239	461	513	513	423	441	458	-17.00
240	315	315	318	762	767	772	7.00
241	1257	1265	1265	1625	1628	1632	-1.00
242	874	881	883	843	863	893	41.00
243	136	1011	1013	1018	1475	1755	-140.00
244	1782	1785	1848	2000	2002	2004	-62.00
245	1509	1622	1623	2121	2142	2173	-62.00
246	324	324	423	787	875	956	70.00
247	248	248	354	373	427	478	-1.00
248	918	918	919	1686	1689	1691	4.00
249	12	13	14	17	19	21	2.00
250	263	478	478	252	308	370	-97.00
251	904	938	940	1849	1918	1963	78.00
252	33	33	436	36	265	389	-50.00
253	293	375	375	294	319	338	-38.00
254	212	212	212	209	211	213	4.00
255	63	63	66	66	66	66	-3.00
256	572	647	649	977	1012	1067	13.00
257	172	172	172	385	387	388	3.00
258	452	455	456	442	515	576	130.00
259	336	460	461	744	813	897	28.00
260	691	699	700	1205	1208	1212	-2.00
261	490	492	496	476	486	496	14.00
262	197	245	245	188	226	254	18.00
263	370	429	435	358	368	382	-41.00
264	219	219	220	219	221	223	3.00
265	225	234	234	215	229	241	17.00
266	643	652	655	643	679	707	52.00
267	12	12	14	21	92	161	138.00
268	61	61	87	62	67	72	-16.00
269				419	438	453	
270	329	330	339	316	330	340	14.00
271	100	100	312	86	115	142	-156.00
272	23	23	205	19	111	199	-2.00

Comparison of Model and Current Traffic Zone Projections
Model includes Pending development, Current 2/1/2011 Projections from WILMAPCO
TAZ=Traffic Zone M10 = Model 2010 M15=Model 2015 M20=Model 2020
W10 = Current Projections 2010 W15 – Current 2015 W20- Current 2020

TAZ	M10	M15	M20	W10	W15	W20	(W20 – W10) – (H20 – H10)
273	177	177	180	172	195	216	41.00
274	52	697	1187	52	317	813	-374.00
275	275	374	374	274	297	318	-55.00
276	299	299	300	286	308	327	40.00
277	158	158	275	154	228	298	27.00
278	341	346	353	333	398	458	113.00
279	195	469	469	163	399	508	71.00
280	82	82	1245	77	420	715	-525.00
281	40	40	271	29	90	149	-111.00
282	39	40	41	37	38	38	-1.00
283	85	85	140	77	87	97	-35.00
284	82	82	749	78	213	344	-401.00
285	9	9	9	12	14	16	4.00
286				0	0	0	
287	21	21	24	17	19	20	.0
288	106	106	112	101	116	128	21.00
289	171	392	403	164	209	252	-144.00
290	3	3	3	3	13	23	20.00
291	4	9	380	6	292	362	-20.00
292	34	109	109	32	89	145	38.00
293	153	395	395	147	220	288	-101.00
294	42	43	44	54	62	70	14.00
295	1	1	4	1	5	9	5.00
296	150	153	175	144	189	230	61.00
297	186	186	189	205	217	227	19.00
298	22	22	24	22	40	58	34.00
299	16	16	16	28	44	60	32.00
300	139	238	239	141	172	201	-40.00
301	101	104	105	75	103	129	50.00
302	416	829	829	394	505	620	-187.00
303	413	703	704	420	555	716	5.00
304	328	328	328	315	355	391	76.00
305	99	99	100	98	119	138	39.00
306	27	27	30	32	48	63	28.00
307	299	299	299	309	332	350	41.00
308	2	5	5	11	25	40	26.00
309	93	93	543	89	381	615	76.00
310	88	88	239	129	158	184	-96.00
311	146	146	147	140	146	150	9.00

Comparison of Model and Current Traffic Zone Projections
Model includes Pending development, Current 2/1/2011 Projections from WILMAPCO
TAZ=Traffic Zone M10 = Model 2010 M15=Model 2015 M20=Model 2020
W10 = Current Projections 2010 W15 – Current 2015 W20- Current 2020

TAZ	M10	M15	M20	W10	W15	W20	(W20 – W10) – (H20 – H10)
312	11	11	284	11	78	142	-142.00
313	115	115	116	108	135	159	50.00
314	14	14	132	13	200	398	267.00
315	223	227	236	590	616	642	39.00
316	481	481	484	478	590	667	186.00
317	137	137	137	139	147	155	16.00
318	56	56	61	70	77	84	9.00
319	0	0	245	673	839	985	67.00
320	366	427	429	361	382	393	-31.00
321	332	882	885	318	422	538	-333.00
322	295	295	324	350	418	480	101.00
323	76	76	77	80	81	83	2.00
324	626	626	628	608	610	612	2.00
325	109	109	109	525	527	528	3.00
326				0	0	0	
327	2	2	4	10	12	13	1.00
328	242	242	245	595	621	657	59.00
329	1	1	1	1	1	1	.0
330				248	248	248	
331	12	12	12	11	13	14	3.00
332				0	0	0	
333	1590	1592	1594	2149	2153	2151	-2.00
334	79	257	257	75	120	161	-92.00
335				0	0	0	
336	89	337	340	81	175	232	-100.00
337	284	284	323	296	318	336	1.00
338	398	402	425	401	460	513	85.00
339	314	314	592	350	626	916	288.00
340	6	6	6	75	219	381	306.00
341				105	108	110	
342	125	127	131	128	130	132	-2.00
343	10	10	10	10	10	10	.0
344	426	431	476	541	570	598	7.00
345	139	139	140	132	133	133	.0

APPENDIX B – A rigorous discussion of calculation of probabilities and factors for future time projection periods.

The logistic regression uses the characteristics the last five years to assign the probability to each piece of land that it was developed during this time. In other words, given the information we had between 2006 and 2010, we derived the absolute probability that a plot of land with specific characteristics was actually developed. Because the logistic regression tries to make as good a fit as possible, the sum of these absolute probabilities equals the total amount of development that actually occurred. In mathematical notation, the logistic regression estimated the following probability:

1) $$P_i\,(D_i(2010,i)=1 \mid X_i(2006-2010,i)\ ,D_i(2006,i)=0)$$

The next step involved making a forecast of development in the next five years. To do this, we made two assumptions. The first is that the total amount of development that will occur in the next five years is known with certainty (estimated from Delaware's population and macroeconomic projections). For example, we assumed that 9,950 plots of land will be developed between 2011 and 2015. Then we assumed that the relative probability that a plot of land will be developed in the next five years equals the relative probability that it was developed in the last five years. In other words, the relative probability that the plot of land was developed between 2006 and 2010 was assumed to equal the relative probability that the plot of land was developed between 2011 and 2015.

To calculate this relative probability for each plot of land, we first limited the sample to those plots of land that were not developed as of 2011. Then we multiplied the lagged probability that each one would have been developed between 2006 and 2010 by a scalar. That scalar equaled the expected future development (9,950) divided by the sum of the original lagged probabilities. This operation normalized the probabilities in such a way to maintain our two assumptions. It also gave us the expected probability that development would occur for each plot of land between 2011 and 2015. The mathematical expression for this is:

2) $$P_i\,(D_i(2015,i)=1 \mid X_i(2011-2015,i)\ ,D_i(2011,i)=0)=E[D_i(2015,i)]\approx$$
$$P_i\,(D_i2010i=1 \mid X_i(2006-2010,i)\ ,D_i(2006,i)=0)\times(D_i(2010,i)\times[\![Assumed\ Development]\!]_i(2011-2015))$$

To iterate the five year forecasts into the future, the same logic would imply the following mathematical equations:

3) $$P_i\,(D_i(2020,i)=1 \mid X_i(2016-2020,i)\ ,D_i(2015,i)=0)\approx$$
$$P_i\,(D_i(2015,i)=1 \mid X_i(2011-2015,i)\ ,D_i(2011,i)=0)\times(D_i(2015,i)\times[\![Assumed\ Development]\!]_i(2016-2$$

However, we cannot actually implement equation 3, because we do not know what independent variables will exist in the future ($X_{2011\text{-}2015,i}$) or what future development occurs ($D_{2015,i}$). However, we have an approximation for future development given by equation 2, ($E[D_{2015,i}]$), and we know that the future independent variables are affected by development that will occur. Thus, we use what development we think will occur to update what independent variables we will expect to see in the future.[2]

4) $$P_i\,(D_i(2020,i)=1 \mid X_i(2016-2020,i)\ ,D_i(2015,i)=0)\approx$$
$$P_i\,(D_i(2015,i)=1 \mid E[X_i(2011-2015,i)]\ ,D_i(2011,i)=0)\times(E[D_i(2015,i)]\times[\![Assumed\ Development]\!]_i(201$$

[2] One should keep in mind that an approximation is being approximated in this step, so any error in the original model will be compounded.

We assume that the probability of development in 2015 has the same relative probabilities predicted by the original model. We are being loose here with the mathematical notation for a reason. By saying that a probability is conditional on certain event, one implies that event is known with certainty. However, we chose this notation to show a comparison with equation 1, the probability derived from a logistic regression.

The major point of equation 4 is that left term is derived by updating our expectations for the independent variables and applying these new variables to the original logistic regression. In other words, the 2020 forecast is based on events that occurred between 2011 and 2015. Since it is currently 2011, we use our 2015 predictions to infer what those changes are likely to be.

To estimate the total probability that a parcel is developed over the next ten years, we would ideally like to use the formula:

5)

$$P(D_i 2020 = 1 \mid X_i(2011 - 2020)\ , D_i 2011 = 0) = P(D_i 2015 = 1 \mid X_i(2011 - 2015)\ , D_i 2011 = 0) + P(D_i 2015$$

As detailed earlier, all of these probabilities on the right hand side of the equation had to be approximated. Therefore, simply switching out each one with its appropriate approximation yields iterated ten year forecast.

Next, we detail how we updated the independent variables using our original predictions for 2015. There were 6 variables: NOTLOT, COMLOT, CAT90, SEWER, TAZDEV, and INSUBDIV. We now describe the assumptions and calculations behind the updates in each of these variables.

NOTLOT: This variable indicates that a parcel of land has not been turned into a developable lot. We think of development as generally following three stages:

1 – parcel not a developable lot (NOTLOT = 1)
2 – parcel becomes a developable lot (NOTLOT = 0)
3 – developable lot is developed (D=1)

Since we assume that parcels follow this path to development, only those parcels that have yet to become a developable lot are included in the discussion below. Second we assume that there is always a constant number of developable lots at any time. This assumption implies that a parcel must become a developable lot (1→2) every time a parcel is developed (2→3). That is, actual development is assumed to pull parcels from the first stage to the second stage.

6.
$$\sum_{j=1}^{N}(NOTLOT_{2016,j}) = \sum_{j=1}^{N}(NOTLOT_{2011,j}) - Assumed\ Development_{2015-2011}$$

This also equals the sum of the probabilities that a parcel that is not ready to be developed in 2010 remains in the same state as of 2016.

7.

$$\Sigma_j(j = 1)^N ([\![NOTLOT]\!]_i(2016, j)) = \sum_i(i = 1)^N [\![P_i i ([\![NOTLOT]\!]_i 2016 = 1 \mid [\![NOTLOT]\!]_i 2011$$

The only other factor to consider is which parcels are most likely to become a developable lot. We assumed that the probability that the land would remain an undevelopable parcel is proportional to the probability that land was not developed.

8.
$$P([\![NOTLOT]\!]_i 2016 = 1 \mid [\![NOTLOT]\!]_i 2011 = 1) = C \times P(D_i 2016 = 0)$$

C is the constant of proportionality that needs to be determined.

Equations 6, 7, and 8 implies that

9. $$\sum_{j=1}^{N}(NOTLOT_{2011,j}) - Assumed\ Development_{2015-2011} = C \times \sum_{i=1}^{N}(P(D_{2016} = 0))$$

Solving for C yielded the final equation:

10. $$C = \frac{\sum_{j=1}^{N}(NOTLOT_{2011,j}) - Assumed\ Development_{2015-2011}}{\sum_{i=1}^{N}(P(D_{2016} = 0))}$$

This constant was inserted into equation 8 to estimate the probability that a parcel would not be a developable lot in 2015. Were this model to be further developed in the future, we would recommend that the process of parcels being turned into developable lots be modeled separately.

CAT90: This variable represents whether the observation was a lot in 1990. The purpose of this variable was to flag properties that have been prepared for development for a long time, but have not yet developed. The first assumption we made was that any piece of developable land that was unprepared for development in 1990 would not be flagged. The second assumption was that any piece of land that developed between 2011 and 2015 would no longer be flagged. Thus, the expected value of this variable was:

11. $$E[CAT90_{2016}] = \begin{cases} 0 & if\ CAT90_{2010} = 0 \\ P(D_{2016} = 0) & if\ CAT90_{2010} = 1 \end{cases}$$

INSUBDIV: Next, we modeled whether a parcel was expected to be in a subdivision in the future. We assumed that any current subdivisions will remain subdivisions in the future. We also assumed that all parcels that become developable lots are given a subdivision. Thus, the expected value that an undeveloped parcel becomes a developable lot is equals the same probability that it gets a subdivision. Any other properties were assumed not to be in a subdivision.

12. $$E[INSUBDIV_{2016}] = \begin{cases} 1 & if\ INSUBDIV_{2010} = 1 \\ P(NOTLOT_{2015} = 0) & if\ INSUBDIV_{2010} = 0 \quad NOTLOT_{2010} = 1 \\ 0 & else \end{cases}$$

TAZDEV: This variable is intended to model the growth of development that occurred for all other parcels in the traffic analysis zone (TAZ). This was done by first estimating the potential predicted amount of development that was found to occur in each TAZ and dividing that number by the predicted amount of land that could be developed in each TAZ. The numerator was merely the sum of $E[D_{2015,i}]$ in each TAZ. The denominator was calculated as the sum of the following function over all parcels in a particular TAZ:

13. $$DENOM = \begin{cases} 1 & if\ NOTLOT_{2010} = 0 \\ P(NOTLOT_{2015} = 0) & if\ NOTLOT_{2010} = 1 \end{cases}$$

COMLOT: We assume that the same commercial zoning patterns will exist in the future as they do today. That is, we do not assume that development over the next five years will influence the commercial zoning of particular lots. Future zoning proposals could easily be analyzed by updating the model with that hypothetical situation.

14. $$E[\ COMLOT_{2016}\ ] = COMLOT_{2011}$$

SEWER: Similar to COMLOT We assume that the same sewer districts will exist in the future as they do today. Again, modeling different scenarios would imply different development patterns.

15. $$E[\ SEWER_{2016}\ ] = SEWER_{2011}$$

APPENDIX C – Scripts used to classify properties

```
if (meanacre=0)size=9.
if (meanacre>0 and meanacre le .2)size=1.
if (meanacre>0.2 and meanacre le 1)size=2.
if (meanacre>1.0 and meanacre le 2)size=3.
if (meanacre>2 and meanacre le 5)size=4.
if (meanacre>5.0 and meanacre le 10)size=5.
if (meanacre>10 and meanacre le 20)size=6.
if (meanacre>20 and meanacre le 100)size=7.
if (meanacre> 100)size=8 .
EXECUTE.

comment replace year below to generate yearly profile.

IF  ( ~( abegyear <= 1999 & aendyear >= 1999) ) CATEG1999='NOTEXIST'.
EXECUTE.
IF  (zoning01 = 'BP' or zoning01 = 'CN' or zoning01 = 'CR' or zoning01 = 'EX' or
zoning01 = 'HI' or zoning01 = 'I' or zoning01 = 'ON' or zoning01 = 'OR'  & categ1999= "
) CATEG1999='COM'.
EXECUTE.
IF  (openpubprv = 'y' & categ1999= " ) CATEG1999='OPENSPACE'.
EXECUTE.
IF  ( agpdr = 'AGPM' | agdist = 'y' & categ1999= " ) CATEG1999='Ag Preservation'.
EXECUTE.
IF  ( pclass = 'EC' & categ1999= " ) CATEG1999='Exempt C'.
EXECUTE.
IF  ( pclass = 'I' & categ1999= " ) CATEG1999='Industrial'.
EXECUTE.
IF  ( pclass = 'ER' & categ1999= " ) CATEG1999='Exempt R'.
EXECUTE.
IF  ( pclass = 'U' & categ1999= " ) CATEG1999='Utility'.
EXECUTE.
IF  ( pclass = 'C' & categ1999= " ) CATEG1999='Assessed Commercial'.
EXECUTE.
IF  (size = 1 & bldg01 > 0 & categ1999= " ) CATEG1999='BLT very small'.
EXECUTE.
IF  (size = 1 & bldg01 = 0 & categ1999= " ) CATEG1999='LOT very small'.
EXECUTE.
IF  (size = 2 & bldg01 = 0 & categ1999= " ) CATEG1999='LOT small'.
EXECUTE.
IF  (size = 2 & bldg01 > 0 & categ1999= " ) CATEG1999='BLT small'.
EXECUTE.
IF  (size = 3 & bldg01 = 0 & categ1999= " ) CATEG1999='LOT med'.
EXECUTE.
```

```
IF  (size = 3 & bldg01 > 0 & categ1999= " ) CATEG1999='BLT med'.
EXECUTE.
IF  (size = 4 & bldg01 = 0 & categ1999= " ) CATEG1999='LOT large'.
EXECUTE.
IF  (size = 4 & bldg01 > 0 & categ1999= " ) CATEG1999='BLT large'.
EXECUTE.
IF  (size = 5 & categ1999= " ) CATEG1999='PLOT very small'.
EXECUTE.
IF  (size = 6 & categ1999= " ) CATEG1999='PLOT small'.
EXECUTE.
IF  (size = 7 & categ1999= " ) CATEG1999='PLOT medium'.
EXECUTE.
IF  ( size = 8 & categ1999= " ) CATEG1999='PLOT large'.
EXECUTE.

comment ***********************************************************.

IF  ( ~( abegyear <= 2000 & aendyear >= 2000) ) CATEG2000='NOTEXIST'.
EXECUTE.
IF  (zoning00 = 'BP' or zoning00 = 'CN' or zoning00 = 'CR' or zoning00 = 'EX' or
zoning00 = 'HI' or zoning00 = 'I' or zoning00 = 'ON' or zoning00 = 'OR'  & categ2000= "
) CATEG2000='COM'.
EXECUTE.
IF  (openpubprv = 'y' & categ2000= " ) CATEG2000='OPENSPACE'.
EXECUTE.
IF  ( agpdr = 'AGPM' | agdist = 'y' & categ2000= " ) CATEG2000='Ag Preservation'.
EXECUTE.
IF  ( pclass = 'EC' & categ2000= " ) CATEG2000='Exempt C'.
EXECUTE.
IF  ( pclass = 'I' & categ2000= " ) CATEG2000='Industrial'.
EXECUTE.
IF  ( pclass = 'ER' & categ2000= " ) CATEG2000='Exempt R'.
EXECUTE.
IF  ( pclass = 'U' & categ2000= " ) CATEG2000='Utility'.
EXECUTE.
IF  ( pclass = 'C' & categ2000= " ) CATEG2000='Assessed Commercial'.
EXECUTE.
IF  (size = 1 & bldg00 > 0 & categ2000= " ) CATEG2000='BLT very small'.
EXECUTE.
IF  (size = 1 & bldg00 = 0 & categ2000= " ) CATEG2000='LOT very small'.
EXECUTE.
IF  (size = 2 & bldg00 = 0 & categ2000= " ) CATEG2000='LOT small'.
EXECUTE.
IF  (size = 2 & bldg00 > 0 & categ2000= " ) CATEG2000='BLT small'.
EXECUTE.
IF  (size = 3 & bldg00 = 0 & categ2000= " ) CATEG2000='LOT med'.
```

```
EXECUTE.
IF  (size = 3 & bldg00 > 0 & categ2000= " ) CATEG2000='BLT med'.
EXECUTE.
IF  (size = 4 & bldg00 = 0 & categ2000= " ) CATEG2000='LOT large'.
EXECUTE.
IF  (size = 4 & bldg00 > 0 & categ2000= " ) CATEG2000='BLT large'.
EXECUTE.
IF  (size = 5 & categ2000= " ) CATEG2000='PLOT very small'.
EXECUTE.
IF  (size = 6 & categ2000= " ) CATEG2000='PLOT small'.
EXECUTE.
IF  (size = 7 & categ2000= " ) CATEG2000='PLOT medium'.
EXECUTE.
IF  ( size = 8 & categ2000= " ) CATEG2000='PLOT large'.
EXECUTE.

comment **********************************************************.
IF  ( ~( abegyear <= 2001 & aendyear >= 2001) ) CATEG2001='NOTEXIST'.
EXECUTE.
IF  (zoning01 = 'BP' or zoning01 = 'CN' or zoning01 = 'CR' or zoning01 = 'EX' or
zoning01 = 'HI' or zoning01 = 'I' or zoning01 = 'ON' or zoning01 = 'OR'  & categ2001= "
) CATEG2001='COM'.
EXECUTE.
IF  (openpubprv = 'y' & categ2001= " ) CATEG2001='OPENSPACE'.
EXECUTE.
IF  ( agpdr = 'AGPM' | agdist = 'y' & categ2001= " ) CATEG2001='Ag Preservation'.
EXECUTE.
IF  ( pclass = 'EC' & categ2001= " ) CATEG2001='Exempt C'.
EXECUTE.
IF  ( pclass = 'I' & categ2001= " ) CATEG2001='Industrial'.
EXECUTE.
IF  ( pclass = 'ER' & categ2001= " ) CATEG2001='Exempt R'.
EXECUTE.
IF  ( pclass = 'U' & categ2001= " ) CATEG2001='Utility'.
EXECUTE.
IF  ( pclass = 'C' & categ2001= " ) CATEG2001='Assessed Commercial'.
EXECUTE.
IF  (size = 1 & bldg01 > 0 & categ2001= " ) CATEG2001='BLT very small'.
EXECUTE.
IF  (size = 1 & bldg01 = 0 & categ2001= " ) CATEG2001='LOT very small'.
EXECUTE.
IF  (size = 2 & bldg01 = 0 & categ2001= " ) CATEG2001='LOT small'.
EXECUTE.
IF  (size = 2 & bldg01 > 0 & categ2001= " ) CATEG2001='BLT small'.
EXECUTE.
IF  (size = 3 & bldg01 = 0 & categ2001= " ) CATEG2001='LOT med'.
```

```
EXECUTE.
IF  (size = 3 & bldg01 > 0 & categ2001= " ) CATEG2001='BLT med'.
EXECUTE.
IF  (size = 4 & bldg01 = 0 & categ2001= " ) CATEG2001='LOT large'.
EXECUTE.
IF  (size = 4 & bldg01 > 0 & categ2001= " ) CATEG2001='BLT large'.
EXECUTE.
IF  (size = 5 & categ2001= " ) CATEG2001='PLOT very small'.
EXECUTE.
IF  (size = 6 & categ2001= " ) CATEG2001='PLOT small'.
EXECUTE.
IF  (size = 7 & categ2001= " ) CATEG2001='PLOT medium'.
EXECUTE.
IF  ( size = 8 & categ2001= " ) CATEG2001='PLOT large'.
EXECUTE.

comment **********************************************************.

IF  ( ~( abegyear <= 2002 & aendyear >= 2002) ) CATEG2002='NOTEXIST'.
EXECUTE.
IF  (zoning02 = 'BP' or zoning02 = 'CN' or zoning02 = 'CR' or zoning02 = 'EX' or
zoning02 = 'HI' or zoning02 = 'I' or zoning02 = 'ON' or zoning02 = 'OR'  & categ2002= "
) CATEG2002='COM'.
EXECUTE.
IF  (openpubprv = 'y' & categ2002= " ) CATEG2002='OPENSPACE'.
EXECUTE.
IF  ( agpdr = 'AGPM' | agdist = 'y' & categ2002= " ) CATEG2002='Ag Preservation'.
EXECUTE.
IF  ( pclass = 'EC' & categ2002= " ) CATEG2002='Exempt C'.
EXECUTE.
IF  ( pclass = 'I' & categ2002= " ) CATEG2002='Industrial'.
EXECUTE.
IF  ( pclass = 'ER' & categ2002= " ) CATEG2002='Exempt R'.
EXECUTE.
IF  ( pclass = 'U' & categ2002= " ) CATEG2002='Utility'.
EXECUTE.
IF  ( pclass = 'C' & categ2002= " ) CATEG2002='Assessed Commercial'.
EXECUTE.
IF  (size = 1 & bldg02 > 0 & categ2002= " ) CATEG2002='BLT very small'.
EXECUTE.
IF  (size = 1 & bldg02 = 0 & categ2002= " ) CATEG2002='LOT very small'.
EXECUTE.
IF  (size = 2 & bldg02 = 0 & categ2002= " ) CATEG2002='LOT small'.
EXECUTE.
IF  (size = 2 & bldg02 > 0 & categ2002= " ) CATEG2002='BLT small'.
EXECUTE.
```

```
IF  (size = 3 & bldg02 = 0 & categ2002= " ) CATEG2002='LOT med'.
EXECUTE.
IF  (size = 3 & bldg02 > 0 & categ2002= " ) CATEG2002='BLT med'.
EXECUTE.
IF  (size = 4 & bldg02 = 0 & categ2002= " ) CATEG2002='LOT large'.
EXECUTE.
IF  (size = 4 & bldg02 > 0 & categ2002= " ) CATEG2002='BLT large'.
EXECUTE.
IF  (size = 5 & categ2002= " ) CATEG2002='PLOT very small'.
EXECUTE.
IF  (size = 6 & categ2002= " ) CATEG2002='PLOT small'.
EXECUTE.
IF  (size = 7 & categ2002= " ) CATEG2002='PLOT medium'.
EXECUTE.
IF  ( size = 8 & categ2002= " ) CATEG2002='PLOT large'.
EXECUTE .

comment ***********************************************************.

IF  ( ~( abegyear <= 2003 & aendyear >= 2003) ) CATEG2003='NOTEXIST'.
EXECUTE.
IF  (zoning03a = 'BP' or zoning03a = 'CN' or zoning03a = 'CR' or zoning03a = 'EX' or
zoning03a = 'HI' or zoning03a = 'I' or zoning03a = 'ON' or zoning03a = 'OR'  &
categ2003= " ) CATEG2003='COM'.
EXECUTE.
IF  (openpubprv = 'y' & categ2003= " ) CATEG2003='OPENSPACE'.
EXECUTE.
IF  ( agpdr = 'AGPM' | agdist = 'y' & categ2003= " ) CATEG2003='Ag Preservation'.
EXECUTE.
IF  ( pclass = 'EC' & categ2003= " ) CATEG2003='Exempt C'.
EXECUTE.
IF  ( pclass = 'I' & categ2003= " ) CATEG2003='Industrial'.
EXECUTE.
IF  ( pclass = 'ER' & categ2003= " ) CATEG2003='Exempt R'.
EXECUTE.
IF  ( pclass = 'U' & categ2003= " ) CATEG2003='Utility'.
EXECUTE.
IF  ( pclass = 'C' & categ2003= " ) CATEG2003='Assessed Commercial'.
EXECUTE.
IF  (size = 1 & bldg03 > 0 & categ2003= " ) CATEG2003='BLT very small'.
EXECUTE.
IF  (size = 1 & bldg03 = 0 & categ2003= " ) CATEG2003='LOT very small'.
EXECUTE.
IF  (size = 2 & bldg03 = 0 & categ2003= " ) CATEG2003='LOT small'.
EXECUTE.
IF  (size = 2 & bldg03 > 0 & categ2003= " ) CATEG2003='BLT small'.
```

```
EXECUTE.
IF  (size = 3 & bldg03 = 0 & categ2003= " ) CATEG2003='LOT med'.
EXECUTE.
IF  (size = 3 & bldg03 > 0 & categ2003= " ) CATEG2003='BLT med'.
EXECUTE.
IF  (size = 4 & bldg03 = 0 & categ2003= " ) CATEG2003='LOT large'.
EXECUTE.
IF  (size = 4 & bldg03 > 0 & categ2003= " ) CATEG2003='BLT large'.
EXECUTE.
IF  (size = 5 & categ2003= " ) CATEG2003='PLOT very small'.
EXECUTE.
IF  (size = 6 & categ2003= " ) CATEG2003='PLOT small'.
EXECUTE.
IF  (size = 7 & categ2003= " ) CATEG2003='PLOT medium'.
EXECUTE.
IF  ( size = 8 & categ2003= " ) CATEG2003='PLOT large'.
EXECUTE .

comment ***********************************************************.

IF  ( ~( abegyear <= 2004 & aendyear >= 2004) ) CATEG2004='NOTEXIST'.
EXECUTE.
IF  (zoning04 = 'BP' or zoning04 = 'CN' or zoning04 = 'CR' or zoning04 = 'EX' or
zoning04 = 'HI' or zoning04 = 'I' or zoning04 = 'ON' or zoning04 = 'OR'  & categ2004= "
) CATEG2004='COM'.
EXECUTE.
IF  (openpubprv = 'y' & categ2004= " ) CATEG2004='OPENSPACE'.
EXECUTE.
IF  ( agpdr = 'AGPM' | agdist = 'y' & categ2004= " ) CATEG2004='Ag Preservation'.
EXECUTE.
IF  ( pclass = 'EC' & categ2004= " ) CATEG2004='Exempt C'.
EXECUTE.
IF  ( pclass = 'I' & categ2004= " ) CATEG2004='Industrial'.
EXECUTE.
IF  ( pclass = 'ER' & categ2004= " ) CATEG2004='Exempt R'.
EXECUTE.
IF  ( pclass = 'U' & categ2004= " ) CATEG2004='Utility'.
EXECUTE.
IF  ( pclass = 'C' & categ2004= " ) CATEG2004='Assessed Commercial'.
EXECUTE.
IF  (size = 1 & bldg04 > 0 & categ2004= " ) CATEG2004='BLT very small'.
EXECUTE.
IF  (size = 1 & bldg04 = 0 & categ2004= " ) CATEG2004='LOT very small'.
EXECUTE.
IF  (size = 2 & bldg04 = 0 & categ2004= " ) CATEG2004='LOT small'.
EXECUTE.
```

```
IF  (size = 2 & bldg04 > 0 & categ2004= " ) CATEG2004='BLT small'.
EXECUTE.
IF  (size = 3 & bldg04 = 0 & categ2004= " ) CATEG2004='LOT med'.
EXECUTE.
IF  (size = 3 & bldg04 > 0 & categ2004= " ) CATEG2004='BLT med'.
EXECUTE.
IF  (size = 4 & bldg04 = 0 & categ2004= " ) CATEG2004='LOT large'.
EXECUTE.
IF  (size = 4 & bldg04 > 0 & categ2004= " ) CATEG2004='BLT large'.
EXECUTE.
IF  (size = 5 & categ2004= " ) CATEG2004='PLOT very small'.
EXECUTE.
IF  (size = 6 & categ2004= " ) CATEG2004='PLOT small'.
EXECUTE.
IF  (size = 7 & categ2004= " ) CATEG2004='PLOT medium'.
EXECUTE.
IF  ( size = 8 & categ2004= " ) CATEG2004='PLOT large'.
EXECUTE .

comment ***********************************************************.

IF  ( ~( abegyear <= 2005 & aendyear >= 2005) ) CATEG2005='NOTEXIST'.
EXECUTE.
IF  (zoning05b = 'BP' or zoning05b = 'CN' or zoning05b = 'CR' or zoning05b = 'EX' or
zoning05b = 'HI' or zoning05b = 'I' or zoning05b = 'ON' or zoning05b = 'OR'  &
categ2005= " ) CATEG2005='COM'.
EXECUTE.
IF  (openpubprv = 'y' & categ2005= " ) CATEG2005='OPENSPACE'.
EXECUTE.
IF  ( agpdr = 'AGPM' | agdist = 'y' & categ2005= " ) CATEG2005='Ag Preservation'.
EXECUTE.
IF  ( pclass = 'EC' & categ2005= " ) CATEG2005='Exempt C'.
EXECUTE.
IF  ( pclass = 'I' & categ2005= " ) CATEG2005='Industrial'.
EXECUTE.
IF  ( pclass = 'ER' & categ2005= " ) CATEG2005='Exempt R'.
EXECUTE.
IF  ( pclass = 'U' & categ2005= " ) CATEG2005='Utility'.
EXECUTE.
IF  ( pclass = 'C' & categ2005= " ) CATEG2005='Assessed Commercial'.
EXECUTE.
IF  (size = 1 & bldg05 > 0 & categ2005= " ) CATEG2005='BLT very small'.
EXECUTE.
IF  (size = 1 & bldg05 = 0 & categ2005= " ) CATEG2005='LOT very small'.
EXECUTE.
IF  (size = 2 & bldg05 = 0 & categ2005= " ) CATEG2005='LOT small'.
```

```
EXECUTE.
IF  (size = 2 & bldg05 > 0 & categ2005= " ) CATEG2005='BLT small'.
EXECUTE.
IF  (size = 3 & bldg05 = 0 & categ2005= " ) CATEG2005='LOT med'.
EXECUTE.
IF  (size = 3 & bldg05 > 0 & categ2005= " ) CATEG2005='BLT med'.
EXECUTE.
IF  (size = 4 & bldg05 = 0 & categ2005= " ) CATEG2005='LOT large'.
EXECUTE.
IF  (size = 4 & bldg05 > 0 & categ2005= " ) CATEG2005='BLT large'.
EXECUTE.
IF  (size = 5 & categ2005= " ) CATEG2005='PLOT very small'.
EXECUTE.
IF  (size = 6 & categ2005= " ) CATEG2005='PLOT small'.
EXECUTE.
IF  (size = 7 & categ2005= " ) CATEG2005='PLOT medium'.
EXECUTE.
IF  ( size = 8 & categ2005= " ) CATEG2005='PLOT large'.
EXECUTE .

comment ***********************************************************.

IF  ( ~( abegyear <= 2006 & aendyear >= 2006) ) CATEG2006='NOTEXIST'.
EXECUTE.
IF  (zoning06a = 'BP' or zoning06a = 'CN' or zoning06a = 'CR' or zoning06a = 'EX' or
zoning06a = 'HI' or zoning06a = 'I' or zoning06a = 'ON' or zoning06a = 'OR'  &
categ2006= " ) CATEG2006='COM'.
EXECUTE.
IF  (openpubprv = 'y' & categ2006= " ) CATEG2006='OPENSPACE'.
EXECUTE.
IF  ( agpdr = 'AGPM' | agdist = 'y' & categ2006= " ) CATEG2006='Ag Preservation'.
EXECUTE.
IF  ( pclass = 'EC' & categ2006= " ) CATEG2006='Exempt C'.
EXECUTE.
IF  ( pclass = 'I' & categ2006= " ) CATEG2006='Industrial'.
EXECUTE.
IF  ( pclass = 'ER' & categ2006= " ) CATEG2006='Exempt R'.
EXECUTE.
IF  ( pclass = 'U' & categ2006= " ) CATEG2006='Utility'.
EXECUTE.
IF  ( pclass = 'C' & categ2006= " ) CATEG2006='Assessed Commercial'.
EXECUTE.
IF  (size = 1 & bldg06 > 0 & categ2006= " ) CATEG2006='BLT very small'.
EXECUTE.
IF  (size = 1 & bldg06 = 0 & categ2006= " ) CATEG2006='LOT very small'.
EXECUTE.
```

```
IF  (size = 2 & bldg06 = 0 & categ2006= " ) CATEG2006='LOT small'.
EXECUTE.
IF  (size = 2 & bldg06 > 0 & categ2006= " ) CATEG2006='BLT small'.
EXECUTE.
IF  (size = 3 & bldg06 = 0 & categ2006= " ) CATEG2006='LOT med'.
EXECUTE.
IF  (size = 3 & bldg06 > 0 & categ2006= " ) CATEG2006='BLT med'.
EXECUTE.
IF  (size = 4 & bldg06 = 0 & categ2006= " ) CATEG2006='LOT large'.
EXECUTE.
IF  (size = 4 & bldg06 > 0 & categ2006= " ) CATEG2006='BLT large'.
EXECUTE.
IF  (size = 5 & categ2006= " ) CATEG2006='PLOT very small'.
EXECUTE.
IF  (size = 6 & categ2006= " ) CATEG2006='PLOT small'.
EXECUTE.
IF  (size = 7 & categ2006= " ) CATEG2006='PLOT medium'.
EXECUTE.
IF  ( size = 8 & categ2006= " ) CATEG2006='PLOT large'.
EXECUTE .
comment ***********************************************************.

IF  ( ~( abegyear <= 2007 & aendyear >= 2007) ) CATEG2007='NOTEXIST'.
EXECUTE.
IF  (zoning07 = 'BP' or zoning07 = 'CN' or zoning07 = 'CR' or zoning07 = 'EX' or
zoning07 = 'HI' or zoning07 = 'I' or zoning07 = 'ON' or zoning07 = 'OR'  & categ2007= "
) CATEG2007='COM'.
EXECUTE.
IF  (openpubprv = 'y' & categ2007= " ) CATEG2007='OPENSPACE'.
EXECUTE.
IF  ( agpdr = 'AGPM' | agdist = 'y' & categ2007= " ) CATEG2007='Ag Preservation'.
EXECUTE.
IF  ( pclass = 'EC' & categ2007= " ) CATEG2007='Exempt C'.
EXECUTE.
IF  ( pclass = 'I' & categ2007= " ) CATEG2007='Industrial'.
EXECUTE.
IF  ( pclass = 'ER' & categ2007= " ) CATEG2007='Exempt R'.
EXECUTE.
IF  ( pclass = 'U' & categ2007= " ) CATEG2007='Utility'.
EXECUTE.
IF  ( pclass = 'C' & categ2007= " ) CATEG2007='Assessed Commercial'.
EXECUTE.
IF  (size = 1 & bldg07 > 0 & categ2007= " ) CATEG2007='BLT very small'.
EXECUTE.
IF  (size = 1 & bldg07 = 0 & categ2007= " ) CATEG2007='LOT very small'.
EXECUTE.
```

```
IF  (size = 2 & bldg07 = 0 & categ2007= " ) CATEG2007='LOT small'.
EXECUTE.
IF  (size = 2 & bldg07 > 0 & categ2007= " ) CATEG2007='BLT small'.
EXECUTE.
IF  (size = 3 & bldg07 = 0 & categ2007= " ) CATEG2007='LOT med'.
EXECUTE.
IF  (size = 3 & bldg07 > 0 & categ2007= " ) CATEG2007='BLT med'.
EXECUTE.
IF  (size = 4 & bldg07 = 0 & categ2007= " ) CATEG2007='LOT large'.
EXECUTE.
IF  (size = 4 & bldg07 > 0 & categ2007= " ) CATEG2007='BLT large'.
EXECUTE.
IF  (size = 5 & categ2007= " ) CATEG2007='PLOT very small'.
EXECUTE.
IF  (size = 6 & categ2007= " ) CATEG2007='PLOT small'.
EXECUTE.
IF  (size = 7 & categ2007= " ) CATEG2007='PLOT medium'.
EXECUTE.
IF  ( size = 8 & categ2007= " ) CATEG2007='PLOT large'.
EXECUTE .

comment ***********************************************************.

IF  ( ~( abegyear <= 2008 & aendyear >= 2008) ) CATEG2008='NOTEXIST'.
EXECUTE.
IF  (zoning08 = 'BP' or zoning08 = 'CN' or zoning08 = 'CR' or zoning08 = 'EX' or
zoning08 = 'HI' or zoning08 = 'I' or zoning08 = 'ON' or zoning08 = 'OR'  & categ2008= "
) CATEG2008='COM'.
EXECUTE.
IF  (openpubprv = 'y' & categ2008= " ) CATEG2008='OPENSPACE'.
EXECUTE.
IF  ( agpdr = 'AGPM' | agdist = 'y' & categ2008= " ) CATEG2008='Ag Preservation'.
EXECUTE.
IF  ( pclass = 'EC' & categ2008= " ) CATEG2008='Exempt C'.
EXECUTE.
IF  ( pclass = 'I' & categ2008= " ) CATEG2008='Industrial'.
EXECUTE.
IF  ( pclass = 'ER' & categ2008= " ) CATEG2008='Exempt R'.
EXECUTE.
IF  ( pclass = 'U' & categ2008= " ) CATEG2008='Utility'.
EXECUTE.
IF  ( pclass = 'C' & categ2008= " ) CATEG2008='Assessed Commercial'.
EXECUTE.
IF  (size = 1 & bldg08 > 0 & categ2008= " ) CATEG2008='BLT very small'.
EXECUTE.
IF  (size = 1 & bldg08 = 0 & categ2008= " ) CATEG2008='LOT very small'.
```

```
EXECUTE.
IF  (size = 2 & bldg08 = 0 & categ2008= " ) CATEG2008='LOT small'.
EXECUTE.
IF  (size = 2 & bldg08 > 0 & categ2008= " ) CATEG2008='BLT small'.
EXECUTE.
IF  (size = 3 & bldg08 = 0 & categ2008= " ) CATEG2008='LOT med'.
EXECUTE.
IF  (size = 3 & bldg08 > 0 & categ2008= " ) CATEG2008='BLT med'.
EXECUTE.
IF  (size = 4 & bldg08 = 0 & categ2008= " ) CATEG2008='LOT large'.
EXECUTE.
IF  (size = 4 & bldg08 > 0 & categ2008= " ) CATEG2008='BLT large'.
EXECUTE.
IF  (size = 5 & categ2008= " ) CATEG2008='PLOT very small'.
EXECUTE.
IF  (size = 6 & categ2008= " ) CATEG2008='PLOT small'.
EXECUTE.
IF  (size = 7 & categ2008= " ) CATEG2008='PLOT medium'.
EXECUTE.
IF  ( size = 8 & categ2008= " ) CATEG2008='PLOT large'.
EXECUTE .

comment ***********************************************************.

IF  ( ~( abegyear <= 2009 & aendyear >= 2009) ) CATEG2009='NOTEXIST'.
EXECUTE.
IF  (zoning09a = 'BP' or zoning09a = 'CN' or zoning09a = 'CR' or zoning09a = 'EX' or
zoning09a = 'HI' or zoning09a = 'I' or zoning09a = 'ON' or zoning09a = 'OR'  &
categ2009= " ) CATEG2009='COM'.
EXECUTE.
IF  (openpubprv = 'y' & categ2009= " ) CATEG2009='OPENSPACE'.
EXECUTE.
IF  ( agpdr = 'AGPM' | agdist = 'y' & categ2009= " ) CATEG2009='Ag Preservation'.
EXECUTE.
IF  ( pclass = 'EC' & categ2009= " ) CATEG2009='Exempt C'.
EXECUTE.
IF  ( pclass = 'I' & categ2009= " ) CATEG2009='Industrial'.
EXECUTE.
IF  ( pclass = 'ER' & categ2009= " ) CATEG2009='Exempt R'.
EXECUTE.
IF  ( pclass = 'U' & categ2009= " ) CATEG2009='Utility'.
EXECUTE.
IF  ( pclass = 'C' & categ2009= " ) CATEG2009='Assessed Commercial'.
EXECUTE.
IF  (size = 1 & bldg09 > 0 & categ2009= " ) CATEG2009='BLT very small'.
EXECUTE.
```

```
IF  (size = 1 & bldg09 = 0 & categ2009= " ) CATEG2009='LOT very small'.
EXECUTE.
IF  (size = 2 & bldg09 = 0 & categ2009= " ) CATEG2009='LOT small'.
EXECUTE.
IF  (size = 2 & bldg09 > 0 & categ2009= " ) CATEG2009='BLT small'.
EXECUTE.
IF  (size = 3 & bldg09 = 0 & categ2009= " ) CATEG2009='LOT med'.
EXECUTE.
IF  (size = 3 & bldg09 > 0 & categ2009= " ) CATEG2009='BLT med'.
EXECUTE.
IF  (size = 4 & bldg09 = 0 & categ2009= " ) CATEG2009='LOT large'.
EXECUTE.
IF  (size = 4 & bldg09 > 0 & categ2009= " ) CATEG2009='BLT large'.
EXECUTE.
IF  (size = 5 & categ2009= " ) CATEG2009='PLOT very small'.
EXECUTE.
IF  (size = 6 & categ2009= " ) CATEG2009='PLOT small'.
EXECUTE.
IF  (size = 7 & categ2009= " ) CATEG2009='PLOT medium'.
EXECUTE.
IF  ( size = 8 & categ2009= " ) CATEG2009='PLOT large'.
EXECUTE .

****************************************

IF  (bldg99 > 0  & bldg98 = 0) builtyear=1999.
EXECUTE.

IF  (bldg00 > 0  & bldg99 = 0) builtyear=2000.
EXECUTE.

IF  (bldg01 > 0  & bldg00 = 0) builtyear=2001.
EXECUTE.

IF  (bldg02 > 0  & bldg01 = 0) builtyear=2002.
EXECUTE.

IF  (bldg03 > 0  & bldg02 = 0) builtyear=2003.
EXECUTE.

IF  (bldg04 > 0  & bldg03 = 0) builtyear=2004.
EXECUTE.

IF  (bldg05 > 0  & bldg04 = 0) builtyear=2005.
EXECUTE.
```

```
IF  (bldg06 > 0  & bldg05 = 0) builtyear=2006.
EXECUTE.

IF  (bldg07 > 0  & bldg06 = 0) builtyear=2007.
EXECUTE.

IF  (bldg08 > 0  & bldg07 = 0) builtyear=2008.
EXECUTE.

IF  (bldg09 > 0  & bldg08 = 0) builtyear=2009.
EXECUTE.

IF  (CHAR.SUBSTR(cat99,1,3) = 'LOT') lot00='y'.
EXECUTE.

IF  (CHAR.SUBSTR(cat00,1,3) = 'LOT') lot01='y'.
EXECUTE.

IF  (CHAR.SUBSTR(cat01,1,3) = 'LOT') lot02='y'.
EXECUTE.

IF  (CHAR.SUBSTR(cat02,1,3) = 'LOT') lot03='y'.
EXECUTE.

IF  (CHAR.SUBSTR(cat03,1,3) = 'LOT') lot04='y'.
EXECUTE.

IF  (CHAR.SUBSTR(cat04,1,3) = 'LOT') lot05='y'.
EXECUTE.

IF  (CHAR.SUBSTR(cat05,1,3) = 'LOT') lot06='y'.
EXECUTE.

IF  (CHAR.SUBSTR(cat06,1,3) = 'LOT') lot07='y'.
EXECUTE.

iF  (CHAR.SUBSTR(cat07,1,3) = 'LOT') lot08='y'.
EXECUTE.

IF  (CHAR.SUBSTR(cat08,1,3) = 'LOT') lot09='y'.
EXECUTE.

*****************************************************************************
IF  ( largedev = 'y' & categ2001= '' ) CATEG2001=' FUTURE DEV'.
EXECUTE.
```

```
IF  ( pclass = 'ER' & categ2001= " ) CATEG2001=' Exempt R'.
EXECUTE.

IF  ( pclass = 'EF' & categ2001= " ) CATEG2001=' Exempt F'.
EXECUTE.

IF  (yearcreate = 2001 & bldg01 = 0  & categ2001= " ) CATEG2001='Emply lot created'.
EXECUTE.

IF  (yearcreate = 2001 & bldg01 >= 10000   & categ2001= " ) CATEG2001=' Lot created
and built'.
EXECUTE.

IF  (bldg01 >= 10000   & bldg00 < 10000 & categ2001= " ) CATEG2001=' Lot created'.
EXECUTE.

IF  (bldg01 < 5000 & bldg00 < 5000 & categ2001= " ) CATEG2001=' Open Lot'.
EXECUTe.




****************************************


IF  (CHAR.SUBSTR(cat10,1,4) = 'PLOT'  & zoning10 = 'S') potunits=shapacr .
EXECUTE.


IF  (CHAR.SUBSTR(cat10,1,4) = 'PLOT'  & zoning10 = 'SR') potunits=shapacr / 4 .
EXECUTE.

IF  (CHAR.SUBSTR(cat10,1,4) = 'PLOT'  & zoning10 = 'SE') potunits=shapacr / 3 .
EXECUTE.

IF  (CHAR.SUBSTR(cat10,1,4) = 'PLOT'  & zoning10 = 'ST') potunits=shapacr / 5 .
EXECUTE.

IF  (CHAR.SUBSTR(cat10,1,4) = 'PLOT'  & zoning10 = 'NC2a') potunits= 0.7 * shapacr
/ 2 .
EXECUTE.

IF  (CHAR.SUBSTR(cat10,1,4) = 'PLOT'  & zoning10 = 'NC40') potunits= 0.7 * shapacr
/ 1 .
```

```
EXECUTE.

IF  (CHAR.SUBSTR(cat10,1,4) = 'PLOT'  & zoning10 = 'NC21') potunits= 0.7 * shapacr
/ .5 .
EXECUTE.

IF  (CHAR.SUBSTR(cat10,1,4) = 'PLOT'  & zoning10 = 'NC15') potunits= 0.7 * shapacr
/ .66 .
EXECUTE.

IF  (CHAR.SUBSTR(cat10,1,4) = 'PLOT'  & zoning10 = 'NCpud') potunits= 0.7 *
shapacr / .33 .
EXECUTE.

IF  (CHAR.SUBSTR(cat10,1,4) = 'PLOT'  & zoning10 = 'NC10') potunits= 0.7 * shapacr
/ .25 .
EXECUTE.

IF  (CHAR.SUBSTR(cat10,1,4) = 'PLOT'  & zoning10 = 'NC6.5') potunits= 0.7 *
shapacr / .16 .
EXECUTE.

IF  (CHAR.SUBSTR(cat10,1,4) = 'PLOT'  & zoning10 = 'NC5') potunits= 0.7 * shapacr /
.125 .
EXECUTE.

IF  (CHAR.SUBSTR(cat10,1,4) = 'PLOT'  & zoning10 = 'NCmm') potunits= 0.7 *
shapacr / .125 .
EXECUTE.

IF  (CHAR.SUBSTR(cat10,1,4) = 'PLOT'  & zoning10 = 'Nga') potunits= 0.7 * shapacr /
.05 .
EXECUTE.

IF  (CHAR.SUBSTR(cat10,1,4) = 'PLOT'  & zoning10 = 'NCap') potunits= 0.7 * shapacr
/ .025 .
EXECUTE.

IF  (CHAR.SUBSTR(cat10,1,4) = ) potunits = multiunit .
EXECUTE.



IF  (CHAR.SUBSTR(cat10,1,4) = 'PLOT'  & zoning10 = 'S') potunits=shapacr .
EXECUTE.
```

```
IF  (CHAR.SUBSTR(cat10,1,4) = 'PLOT'  & zoning10 = 'SR') potunits=shapacr / 4 .
EXECUTE.

IF  (CHAR.SUBSTR(cat10,1,4) = 'PLOT'  & zoning10 = 'SE') potunits=shapacr / 3 .
EXECUTE.

IF  (CHAR.SUBSTR(cat10,1,4) = 'PLOT'  & zoning10 = 'ST') potunits=shapacr / 5 .
EXECUTE.

IF  (CHAR.SUBSTR(cat10,1,4) = 'PLOT'  & zoning10 = 'NC2a') potunits= 0.7 * shapacr
/ 2 .
EXECUTE.

IF  (CHAR.SUBSTR(cat10,1,4) = 'PLOT'  & zoning10 = 'NC40') potunits= 0.7 * shapacr
/ 1 .
EXECUTE.

IF  (CHAR.SUBSTR(cat10,1,4) = 'PLOT'  & zoning10 = 'NC21') potunits= 0.7 * shapacr
/ .5 .
EXECUTE.

IF  (CHAR.SUBSTR(cat10,1,4) = 'PLOT'  & zoning10 = 'NC15') potunits= 0.7 * shapacr
/ .66 .
EXECUTE.

IF  (CHAR.SUBSTR(cat10,1,4) = 'PLOT'  & zoning10 = 'NCpud') potunits= 0.7 *
shapacr / .33 .
EXECUTE.

IF  (CHAR.SUBSTR(cat10,1,4) = 'PLOT'  & zoning10 = 'NC10') potunits= 0.7 * shapacr
/ .25 .
EXECUTE.

IF  (CHAR.SUBSTR(cat10,1,4) = 'PLOT'  & zoning10 = 'NC6.5') potunits= 0.7 *
shapacr / .16 .
EXECUTE.

IF  (CHAR.SUBSTR(cat10,1,4) = 'PLOT'  & zoning10 = 'NC5') potunits= 0.7 * shapacr /
.125 .
EXECUTE.

IF  (CHAR.SUBSTR(cat10,1,4) = 'PLOT'  & zoning10 = 'NCmm') potunits= 0.7 *
shapacr / .125 .
EXECUTE.
```

```
IF  (CHAR.SUBSTR(cat10,1,4) = 'PLOT'  & zoning10 = 'Nga') potunits= 0.7 * shapacr /
.05 .
EXECUTE.

IF  (CHAR.SUBSTR(cat10,1,4) = 'PLOT'  & zoning10 = 'NCap') potunits= 0.7 * shapacr
/ .025 .
EXECUTE.
```